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Temporal Dynamics of Public Perceptions toward Water Infrastructure in US Shrinking Cities Before and After the Flint Water Crisis

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Temporal Dynamics of Public Perceptions toward Water Infrastructure in US Shrinking Cities Before and After the Flint Water Crisis

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Abstract

Temporal Dynamics of Public Perceptions toward Water Infrastructure in US Shrinking Cities Before and After the Flint Water Crisis

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Understanding public perceptions allows decision makers to assess public priorities for actions to pursue sustainable infrastructure management. However, since public views change based on new information or events, the cross-sectional sample from previous studies does not account for the temporal dynamics of perceptions. In 2014, Flint, Michigan switched water sources resulting in lead leaching into drinking water and impacts to public health. This study evaluated public perceptions toward water infrastructure providers at two different time periods before (November 2013) and after (June 2016) the Flint Water Crisis, using surveys deployed to residents in 21 US shrinking cities. Two questions of interest from these surveys were statistically modeled to assess the temporal dynamics of public perceptions toward local water providers, specifically: (1) whether individuals trust his/her water provider to make decisions in his/her best interest (*Trust*) and (2) if individuals want to partake in participatory processes with local utilities (*Active*). Random parameter binary probit models were the resulting best-fit models, and used to identify demographic (e.g., age, gender, income) and geographic parameters (cities) influencing *Trust* and *Active*. A likelihood ratio test was conducted to evaluate the independence of two data sets to determine if the public perceptions have changed from 2013 to 2016, which resulted in a 99% confidence that the perceptions should be modeled separately. Shrinking cities comprise the survey sample, a classification of cities that are typically fiscally constrained, experiences infrastructure underutilization, and to which Flint (the location of the water crisis) belongs. This study illustrates the limitations of cross-sectional surveys regarding infrastructure perception in light of new events or information. Additionally, the statistical modeling found that most geographic parameters had homogeneous impacts (i.e. minimal statistical variability across respondents), while demographic parameters had heterogeneous impacts (i.e. statistically varies across respondents) on *Trust* and *Active*. The homogeneous impact of geographic parameters demonstrates the localized significance of utility-customer relationships in shaping perceptions.

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Chapter 1. Introduction

Public perception, a type of information retrieved from a sample of the population, represents how the population perceives particular issues or events at a certain point in time (Dowler et al., 2006; Sadaf, 2011). Researchers have emphasized the importance of evaluating and understanding public perceptions in decision making processes and the importance of incorporating public perceptions in an early stage of a planning phase (Dowler et al., 2006; Faust et al., 2013). Since US policies tend to be strongly influenced by the persistence of the opposition, incorporating public perceptions in the early stage of planning can be critical to implementing strategies that minimize public opposition (Keller et al., 2010; Faust et al., 2016). Prior studies have assessed public perceptions toward various types of infrastructure systems, such as green infrastructure (e.g., Barnhill and Smardon, 2012; Everett et al., 2016), transportation infrastructure (e.g., Podgorski, 2006), and water infrastructure (e.g., Canter et al., 1993; Turgeon et al., 2004; de França Doria, 2010; Faust et al., 2013). However, there are limited studies that focused on identifying temporal changes of public perceptions (Li et al., 2015). This study aims to capture dynamics of public perceptions toward water infrastructure providers before and after a 2014 water related crisis in Flint, Michigan.

The public perceptions of 21 US shrinking cities are evaluated. US shrinking cities are defined as medium and large cities that have experienced a steady population decline from their peak population over multiple decades (Rybczynski and Linneman, 1999). Although many small cities and towns experience urban decline, this study considers only medium and large cities (populations that peaked at approximately 100,000 or more) that have lost at least 30% of their population from their peak population (see Table 1.1). This drastic population loss often results in a corresponding physical infrastructure footprint that is larger than necessary for the current population, consequentially causing the underutilization of infrastructure. This urban decline in cities has significant impacts on infrastructure systems, as well as populations, housing markets, local labor markets, and the viability of urban structures of the region (Kabisch et al., 2006).

To assess public perceptions toward water infrastructures in shrinking cities, two surveys were deployed in November 2013 (see Faust et al. 2016 for more information on the 2013 survey development) and June 2016 to residents in the 21 shrinking cities. In the time between the two survey deployments, the Flint Water Crisis (FWC), a drinking water event, occurred in Flint, Michigan. In April 2014, the City of Flint changed its water source from Lake Huron to Flint River due to financial constraints, but failed to implement adequate treatment for corrosion to prevent lead from leaching into the drinking water (Dixon, 2016; Grinberg, 2016; Snyder, 2016). Later, in September 2015, high blood lead levels were detected in children living in Flint (Bellinger, 2016). Flint switched the water source back to the original supplier (Lake Huron), and the residents were advised to continue not to use tap water for drinking and instead, use filtered or bottled water (Dixon, 2016). To assess if public perceptions toward water infrastructure providers have changed in the time surrounding the FWC, a Likelihood Ratio Test was conducted using models developed with the data from the two surveys (2013 and 2016). It should be noted that it is conjectured that the shift of public perceptions between 2013 and 2016 was primarily attributable to the FWC (and other surrounding attention toward national, aging water infrastructure systems) based on qualitative coding of open-ended responses in the 2016 survey that is not discussed in this thesis. Statistical modeling of the data was performed to identify demographic and geographic parameters that are statistically significant in influencing the likelihood of (1) trusting local water utilities and (2) wanting to partake in participatory processes of local utilities for both years. Additionally, shifts in statistical significance of parameters between 2013 and 2016 from the models were evaluated. A "shift" is defined as a temporal change in the significance of a parameter with reference to the impacts of the parameter on the model of interest from positive to negative (negative to positive), or significant to non-significant (non-significant to significant) between 2013 and 2016. Multiple models were created with the best-fit models discussed in this study (based on Log-likelihood (LL) and Akaike Information Criteria (AIC) values), specifically, random parameter binary probit models that capture the heterogeneity of the population. Statistical findings (and the applied methodology) have the potential to help understand how events and information can trigger temporal dynamics in public perceptions, as well as demographic groups and geographic regions that should be focused on to mitigate opposition toward or improve relationships with water providers.

This document is organized into 6 chapters. Chapter 2 presents the literature review. Content in the literature review includes the definition of public perceptions and general studies pertaining to the assessment of public perceptions (Section 2.1), followed by Section 2.2 that presents information about the surveyed shrinking cities, and finally, a discussion of public perception studies regarding infrastructure systems (Section 2.3). Chapter 3 discusses the study methodology, specifically, the 2016 survey deployment, a timeline providing information about the FWC, the likelihood ratio test conducted to assess the independence of the 2013 and 2016 survey data, and the statistical modeling approach for random parameter binary probit models. Chapter 4 provides descriptive statistic data from the 2013 and 2016 surveys. The results and discussions from statistical modeling are presented in Chapter 5. In Chapter 5, a number of parameters that were statistically significant in both years and how they have shifted from 2013 to 2016 are discussed. Chapter 6 concludes the thesis, providing a summary of the major findings, the contributions to the body of knowledge and the body of practice, limitations, and future studies.

City	Percent decline from peak population	Peak population (Year)	2010 Population (US Census Bureau)
Akron, Ohio	34.5%	290,351 (1960)	199,110
Baltimore, Maryland	34.6%	949,708 (1950)	620,961
Birmingham, Alabama	37.7%	340,887 (1950)	212,237
Buffalo, New York	53.4%	580,132 (1950)	270,240
Camden, New Jersey	37.9%	124,555 (1950)	77,344
Canton, Ohio	37.6%	116,912 (1950)	73,007
Cincinnati, Ohio	41.1%	503,998 (1950)	296,943
Cleveland, Ohio	56.6%	914,808 (1950)	396,815
Dayton, Ohio	46.1%	262,332 (1960)	141,527
Detroit, Michigan	61.4%	1,849,568 (1950)	713,777
Flint, Michigan	43.4%	196,940 (1960)	84,465
Gary, Indiana	55.0%	178,320 (1960)	98,026
Niagara Falls, New York	51.0%	102,394 (1960)	52,200
Pittsburgh, Pennsylvania	54.8%	676,806 (1950)	371,102
Rochester, New York	36.7%	332,488 (1950)	121,923
Saginaw, Michigan	47.5%	98,265 (1960)	51,508
Scranton, Pennsylvania	46.9%	143.333 (1930)	67,244
St. Louis, Missouri	62.7%	856,796 (1950)	537,502
Syracuse, New York	34.2%	220,583 (1950)	75,413
Trenton, New Jersey	33.7%	128,009 (1950)	43,096
Youngstown, Ohio	60.6%	170,002 (1930)	103,020

Table 1.1. US shrinking cities considered in study (Adapted from Faust et al. 2016)

Chapter 2. Literature Review

Chapter 2 reviews previous research conducted on assessing public perceptions, incorporating public perceptions into infrastructure management, and public perception studies on water infrastructures in shrinking cities. Additionally, discussed in this chapter is a brief overview of shrinking cities which is the classification of cities surveyed in this study. Although public perceptions have been thoroughly studied in various fields of research, studies capturing temporal dynamics of perceptions for managing infrastructure are rare. This paper mainly focuses on evaluating temporal changes in public perceptions due to a specific event (i.e. FWC) toward water infrastructure systems.

2.1. Public perception

Public perception can be defined as the views expressed by a randomly selected group of people on particular issues or events at certain points in time (Dowler et al., 2006; Sadaf, 2011). How people generally perceive important matters strongly influences their behavior, and those perceptions have been shown to play a significant role in shaping events (Dowler et al., 2006). Thus, for effective decision making processes, policy makers now assess public perceptions on the basis of research from a variety of disciplines and sectors (e.g., social sciences (LeCroy and Stinson, 2004; Fahmy et al., 2012; Oltra and Sala, 2014), political science (Canoy et al., 2006), healthcare and risk (Dowler et al., 2006), education (Giacalone et al., 2010), environment (Zhang et al., 2007), and biotechnology (Savadori et al., 2004)). **By investigating public perceptions, policy makers can understand public priorities for policy actions, determine the effectiveness of current policy and other available alternatives, measure public understanding, and construct successful communication systems (Dowler et al., 2006).**

Yet, because of its complexity and changeability, policy makers have had difficulty capturing public perceptions and its many implications (Canoy et al., 2006; Dowler et al., 2006). So, instead of trying to assess all its driving factors, they work to establish reliable indicators, and then focus on capturing and interpreting them (Dowler et al., 2006). Dowler et al. (2006) have identified various methods of examining public perceptions for policy makers, e.g., quantitative and qualitative analysis, focus group analysis, survey analysis, mass media content analysis, and behavioral indicator analysis.

Public perception reflects the views of the public at a given point in time. These views are dynamic, making it difficult to base effective policy on one cross-sectional sample. Indeed, public perceptions can fluctuate over time, and how the public perceives an issue at a given moment will not necessarily remain unchanged (Dowler et al., 2006; Li et al., 2015). Research has shown that measuring the long-term relationships between the public and organizations is more effective than measuring short-term communication flows between them (Kimberly, 2004). In spite of this finding, most recent studies on public perceptions have employed cross-sectional surveys, instead of monitoring perception changes over time (Li et al., 2015). This study focuses on capturing changes in public perceptions toward water infrastructure providers before and after a certain event (i.e., FWC).

2.2. Shrinking cities

To provide the context of the populations assessed in this study, a discussion is needed on shrinking cities—municipalities that have experienced steady population declines from their peak populations over multiple decades (Rybczynski and Linneman, 1999; Hollander et al., 2009; Faust et al., 2016). Specifically, this study considers 21 shrinking cities in the United States (listed on Table 1.1) that are medium- or large-sized (i.e., their populations peaked at approximately 100,000 and experienced at least 30% chronic loss since that peak, according to the 2010 census).

From 1900 to 1950, the US experienced urban growth due to industrialization; and during that time, large cities increased in population at a higher rate than small cities (Rybczynski and Linneman, 1999). However, after 1950, technological advances such as expanded air travel, modern telecommunications, and efficient sewer and water treatment facilities fueled the expansion of suburbs, and thus reversed the urban growth trend (Rybczynski and Linneman, 1999; Hollander, 2011). This shrinkage of large US cities had significant negative impacts on populations, housing markets, infrastructure systems, local labor markets, and the viability of the urban structures of entire regions (Kabisch et al., 2006). However, since this mid-century shift, planners and policy makers have typically been growth-centric, mainly considering drivers of suburban population increase such as, industrialization, expansion, and redevelopment. At the same time, they have largely ignored the possibility of urban decline that arises from the same drivers (e.g., de-industrialization within cities) (Pallagst, 2009; Martinez-Fernandez and Wu, 2009).

While the drivers and social dimensions of urban decline have been well researched by political and social scientists, its impacts on infrastructure systems are not well understood (Hollander et al., 2009; Faust et al., 2015). Hollander et al. (2009) determined that, to help shrinking cities handle their infrastructure challenges, the academic planning community must not only address the lack of existing tools for managing these cities, but also the lack of knowledge of how stakeholders actually operate within them.

Table 2.1 summarizes the findings from previous case studies and literature reviews of research on planning and infrastructure management in shrinking cities. Among the various impacts of the shrinkage cited in these findings, this paper focuses on the impacts on water infrastructure.

Researchers	Methodology	Main Findings
Kabisch, S., Haase, A., & Haase, D. (2006)	Case study of extreme stage of shrinkage in eastern Germany, taking a concept modeling approach to predict the shrinkage	Per capita wastewater costs rise as a result of population decrease.
Hummel, D., & Lux, A. (2007)	Case study in Germany identifying relationships between population decline and water infrastructure	Demographic factors (e.g., population size and growth, population structure and age composition, and household number and size) and water demands are interdependent.
Hollander, J. B., Pallagst, K., Schwarz, T., & Popper, F. J. (2009)	Literature review and development of research questions on how to plan for shrinking cities	The academic planning community's consideration of the phenomenon of shrinking cities faces two challenges: (1) applicability of using existing tools for growing communities to shrinking cities; and (2) lack of knowledge of how stakeholders actually operate within shrinking cities.
Martinez-Fernandez, C., & Wu, C. T. (2009)	Case studies of Australian mining cities	Urban growth and decline result from the same drivers. The lack of strategic planning tools for managing change may result in further rapid decline.
Pallagst, K. (2009)	Case studies of three shrinking US cities (Pittsburgh, PA; Youngstown, OH; and San Jose, CA)	The phenomenon of shrinking cities is not limited to post-industrial "Rust-Belt" examples; it happens in other areas of the US, as well. Shrinking and growing can be observed in parallel, and can be observed at both regional and local scales.

Table 2.1. Summary of previous case studies and literature reviews of research on shrinking cities

As the case studies summarized in Table 2.1 indicate, there have been studies regarding possible actions in shrinking cities to adapt their water and wastewater infrastructures to their population decline. At the same time, previous research has identified challenges that shrinking cities face in managing their water infrastructure (Hummel and Lux, 2007; Schwarz and Hoornbeek, 2009; Faust et al., 2016). First, because the integrity of water and wastewater infrastructure systems has to be maintained, these cities find it difficult to reduce the usage of any one part of a system in response to a population decrease (Schwarz and Hoornbeek, 2009). Second, the invisibility of underground infrastructure systems and the as-needed (not proactive) approach to their maintenance make them less adaptable to change (Faust et al., 2016). The financial constraints caused by population decreases pose another significant impediment to effective urban infrastructure management (Hummel and Lux, 2007; Faust et al., 2016). In general, approximately 75 to 80% of infrastructure service costs are fixed, regardless of the volume of water used or the number of users (Hummel and Lux, 2007; Schwarz and Hoornbeek, 2009). Therefore, the per capita water and wastewater costs that individuals have to bear rise in response to population decline (Hummel and Lux, 2007; Schwarz and Hoornbeek, 2009). Consequently, the remaining residents pay dramatically increasing utility bills, which only exacerbates the income inequity in shrinking cities (Faust et al., 2016). Moreover, meeting stringent regulatory requirements has become more challenging for shrinking cities, due to their declining tax bases and other fiscal constraints (Faust et al., 2016).

Internationally, researchers are responding to urban decline, exploring innovative and effective strategies for cities' successful reduction of their municipal footprints to accommodate smaller populations (e.g., Swope, 2006; Hollander et al., 2009). Table 2.2 presents several of the strategies found to be effective for managing infrastructure systems in shrinking cities.

Researchers	Methodology	Practices and Strategies
Bontje, M. (2004)	Case study of Leipzig, Germany	Leipzig has developed two relatively successful strategies to adapt housing stock and infrastructure to the rate of urban decline: reconstruction of neighborhoods into less dense and greener environments; restructuring of unused and vacant industrial spaces.
Schwarz, T., & Hoornbeek, J. (2009)	Literature review and interviews with key infrastructure management personnel in selected areas	Asset management, coordination across infrastructure systems, advanced technologies, use of vacant land for reusable energy and storm water management, and understanding costs associated with urban decline.
USEPA (Unites States Environmental Protection Agency) (2014).	Case study of Saginaw, Michigan	Reuse of vacant and abandoned areas for green space, e.g., passive open space, park and recreation areas, community gardens, commercial agricultural land, and storm water management facilities.

Table 2.2. Practices and strategies for managing infrastructure in shrinking cities

2.3. Public perception toward infrastructures systems

Assessing public perceptions, understanding the determinants of those perceptions, and communicating about perceptions with all stakeholders are critical to successful decision making processes for any infrastructure project (Canter et al., 1993; Faust et al., 2013; Faust et al., 2016). While it is challenging to integrate and optimally implement public perspectives, neglecting them may lead to failure due to public discontent (de França Doria, 2010; Faust et al., 2013; Faust et al., 2016). This attention to opposition, even if only expressed by a small percentage of the public, is that US policies tend to be strongly influenced by the persistence of opposing views (Faust et al., 2016). Additionally, to develop feasible strategies with limited public opposition, communicating about perceptions has to take place during the early stages of planning (Keller et al., 2010; Faust et al., 2013).

Researchers	Methodology	Main Findings
Barnhill, K., & Smardon, R. (2012)	Ran focus groups and analyzed surveys of residents living within the study area (City of Syracuse, NY and three local neighborhoods) to examine public perceptions of infrastructure.	Most focus group participants lacked knowledge about ecological services. Understanding the perceptions of residents toward ecological services, and introducing green infrastructure into their neighborhoods is key to successful implementation.
Everett, G., Lamond, J. E., Morzillo, A. T., Matsler, A. M., & Chan, F. K. S. (2016)	Interviewed residents living near bioswale facilities (installed 1–2, 4–5, and 8–9 years before the study) to examine perceptions toward them.	One of an array of possible green infrastructure facilities, bioswales constitute a highly engineered and modular storm water management system. Public acceptance will be improved with increased awareness of purpose and function, localized maintenance strategies, and customization of facilities to meet residents' needs.
Kirkman, R., & Voulvoulis, N. (2016)	Reviewed previous studies in the U.K. on the role of public communication in planning and delivering waste management infrastructure.	Public perceptions must be taken into account early in the decision making process, with the public informed and engaged from the start. Obtaining positive public perceptions of proposed new infrastructure requires a neutral and credible voice that presents unbiased information about challenges and solutions.
Podgorski, K. V., & Kockelman, K. M. (2006)	Undertook telephone survey of 2,111 Texas residents to examine regional perceptions toward potential toll road projects and policies.	Perceptions varied significantly by region: residents in large urban areas were more aware of toll road projects; residents in small and rural areas were more supportive of using toll tags or paying tolls on existing roads. Demographics (i.e., age and period of residence) and travel characteristics (i.e., traveling distance, use of toll roads, and frequency of toll road use) were revealed to have impact on perception of toll roads.

Table 2.3. Previous research on public perceptions toward infrastructure systems

As summarized in Table 2.3, a number of researchers have assessed public perceptions of different types of infrastructure, e.g., green infrastructure, waste management infrastructure, and transportation infrastructure (see Barnhill and Smardon, 2012; Everett et al., 2016; Kirkman and Voulvoulis, 2016; Podgorski and Kockelman, 2006). These studies not only identified factors that influence public perceptions, but also related their findings to successful management of existing infrastructure or the implementation of new infrastructure (Table 2.3). However, these determining factors and management strategies may not apply specifically to managing water infrastructure in shrinking cities, which is the main interest of this paper.

Bringing the focus back specifically to water infrastructure, Table 2.4 summarizes previous studies on public perceptions of such topics as drinking water quality, health risk, trust of water service, service satisfaction, willingness to pay, water reuse, and privatization of water and energy (Canter et al., 1993; Turgeon et al., 2004; de França Doria, 2010). While this research has identified the parameters affecting perception and determined how these factors can facilitate water infrastructure management, only a few compelling studies have assessed public perceptions toward water infrastructure in shrinking cities.

Table 2.5 presents the findings of recent studies of public perceptions in shrinking US cities. In these studies, researchers conducted statistical analyses of survey data and previously identified geographic or demographic parameters affecting public perceptions toward the retooling of water infrastructure in shrinking US cities (Faust et al., 2016). These analyses showed that understanding public opinion and incorporating it into decision making processes are as important as developing the right strategies for managing infrastructure in shrinking cities to ensure adequate service (Faust et al. 2016).

Researchers	Methodology	Main Findings	Shortcomings
Canter, L. W., Nelson, D. I., & Everett, J. W. (1993)	Literature review	Identification of factors affecting public perceptions of acceptable risk in water quality: involvement in decision making processes; tolerance for being exposed to risk; familiarity with types of risk; and nature of the community.	Demographic factors differ for varying public perceptions. Determinate factors identified in 1993 may have changed over time.
Turgeon, S., Rodriguez, M. J., Thériault, M., & Levallois, P. (2004)	Logistic regression analysis of survey data in Canada	Consumer perception is strongly influenced by water quality variations and geographic location within the distribution system. Socio-economic characteristics of consumers affect their perception of drinking water quality.	Author did not analyze differences between previously collected survey data (1994) and new data (2001).
de França Doria, M. (2010)	Review of literature	Following are factors that modulate perceptions of drinking water quality: sensorial information; risk perception; water chemicals and microbiological parameters; contextual indicators; prior experience; impersonal and interpersonal information; and trust in water companies. Found the implications of the factors affecting policy, management, and research, including the following: 1) to enhance effectiveness, communication strategies should concurrently address several factors affecting perceptions; 2) consumer surveys effectively assess public perceptions of water quality and satisfactions with water service; 3) consumers' perception of water quality is key to their trust in water providers.	Assessment of public perceptions and implications in management did not consider shrinking cities. Changes in perceptions were not considered.
Faust, K., Abraham, D. M., & DeLaurentis, D. (2013).	Binary probit analyses using case study and online survey data	Developed a decision-support framework to incorporate stakeholder insights into decision making processes in early planning stages: 1) system-of-systems approach to the water system; 2) identified demographics affecting stakeholders' perception of the need for and their support of new capital-intensive infrastructure projects.	Data on stakeholder perception was collected only in California. The factors identified as having significant influence on perception may not apply in different locations.

Table 2.4. Previous studies on public perceptions of water infrastructure

Researchers	Methodology	Main Findings
Faust, K. M., Abraham, D. M., & Zamenian, H. (2015)	Created binary probit models using survey data from 21 shrinking US cities	Identified demographic and geographic factors affecting public perceptions toward infrastructure management alternatives. Incorporating public opinion in the early planning stages facilitates the implementation of alternatives, by reducing public opposition.
Faust, K. M., Mannering, F. L., & Abraham, D. M. (2016)	Statistical analysis of survey data from shrinking US cities	Identified groups likely to oppose water infrastructure decommissioning and the factors influencing the likelihood of opposition in shrinking US cities. Provided information on how the public initially perceives policies pursuing sustainable infrastructure systems.
Faust, K. M., Abraham, D. M., & McElmurry, S. P. (2016)	Qualitative analyses of four case studies of shrinking US cities; statistical analyses of survey data collected from 21 shrinking US cities	Identified demographic variables that influence individual perceptions toward five water infrastructure retooling alternatives in shrinking cities. Evaluating public perceptions at a point in time closer to implementation will enable the more accurate incorporation of public views on new policies.

Table 2.5. Recent studies assessing public perceptions on water infrastructure in shrinking cities.

2.4. DEPARTURE POINT

Chapter 2 summarizes previous literature incorporating public perceptions into various disciplines and sectors (e.g. social sciences, political sciences, education, biotechnology, and infrastructure management). Of primary interest to this study is the sub-section discussing public perception studies on water infrastructures in shrinking cities. A main takeaway from previous research is the emphasis on the importance of assessing public perceptions to understand public priorities for policy actions, construct successful communication systems, and implement sustainable infrastructure management alternatives.

However, public perceptions change over time due to new events or information. In spite of the fact that perceptions are dynamic, most recent studies overlooked considering perception beyond a cross-sectional sample. The cross-sectional approach makes it difficult to evaluate effective strategies and policies in light of changing environments. This study focuses on capturing changes in public perceptions toward water infrastructure providers in shrinking cities before and after a certain event (i.e., FWC) to demonstrate and understand both the aggregate perception shifts, as well as the demographic and geographic drivers *of* the aggregate perception shifts. Through subsequent modeling (Chapters 4 and 5) of survey data (Chapter 3), this study seeks to understand how and why different demographics and locations respond to disruption in regard to customer-utility relationships.

Chapter 3. Methodology

This study combines survey analysis techniques and statistical modeling to assess the impact of the FWC, ensuing media attention, and shifting national conversation regarding the state of US water infrastructure on public perceptions. Fig. 3.2 summarizes the methodology.

3.1. Survey deployment

This study seeks to assess the temporal dynamics of public perceptions toward water utility providers before and after the Flint Water Crisis (FWC) in shrinking cities. A classification of shrinking cities in this study is categorized as cities that experience at least 30% of steady population decrease after the peak population of approximately 100,000 or more, a classification into which Flint, Michigan belongs (the location of the FWC). Two data sets are used in the analysis from surveys deployed to 21 US shrinking cities (see Table 1.1) in November 2013 (see Faust et al. 2016 for more information on the 2013 survey development) and a second survey deployed to the general public in the same 21 cities in June 2016. The first survey (2013) was comprised of 445 valid responses, and the second survey (2016) had 438 valid responses. These sample sizes from each of the two surveys provide over 95% confidence level with a 5% confidence interval that the results reflect the total population. The June 2016 survey contained repeated questions, as well as additional questions, assessing public knowledge, awareness, perceptions toward water infrastructure and water utility providers (see Appendix A and B for the 2013 and 2016 survey, respectively). **Of interest to this study are two questions pertaining to the change in public perceptions toward trust in their water providers and individual's wanting to partake in participatory processes.**

The 2016 survey underwent Internal Review Board (IRB) review to receive exempt status at the University of Texas at Austin. The survey was developed and deployed using Qualtrics, LLC, an online survey company. Prior to the deployment, 10 subject-matter experts who have background with survey analyses, water infrastructure, or shrinking cities reviewed the survey for content validation. Additionally, this survey was pre-deployed to 10 individuals in the general public who have less knowledge about the subject to ensure that the survey was accessible and that the intended data was being collected from the survey (pre-deployment responses were not included in the final sample). All respondents were residents over the age of 18 and voluntarily completed the survey.

The timeline below (see Fig. 3.1) summarizes selected events associated with the Flint water crisis from April 2014 to January 2016, which occurred between the two deployed surveys (i.e., November 2013 and June 2016). In April 2014, the City of Flint transitioned its water source to Flint River from Lake Huron for financial reasons (Dixon, 2016; Ganim and Sanchez, 2016). However, Flint failed to treat corrosive water to prevent lead from leaching into the water (Grinberg, 2016; Snyder, 2016). Shortly after, at least two boil-water advisories (August 2014 and September 2014) were announced (Dixon, 2016; Snyder, 2016), and General Motors ceased using Flint provided water due to corrosion within the city water for their engine plant (October 2014) (Dixon, 2016; Snyder, 2016). In January 2015, the University of Michigan at Flint identified high levels of lead at their water fountains (Dixon, 2016). Additionally, in January 2015, the Department of Environmental Quality (DEQ) determined? that no additional requirements were immediately needed for monitoring the level of lead in the Flint River (Dixon, 2016). In June 2015, the US Environmental Protection Agency (USEPA, 2016) announced that the lack of corrosion-control treatment was a major concern (Dixon, 2016; Grinberg, 2016). Dr. Mona Hanna-Attisha, a researcher from Hurley Medical center, reported a high level of lead in children living in Flint (September 2015) (Bellinger, 2016; Dixon, 2016). In early October 2015, the Department of Health and Human Service announced a public health emergency and the City of Flint switched the water source back to the original water supplier by mid-October (Dixon, 2016; Snyder, 2016). The City of Flint declared the state of emergency and residents were told to use filtered or bottle water in January 2016 (CNN Library, 2016; Dixon, 2016).

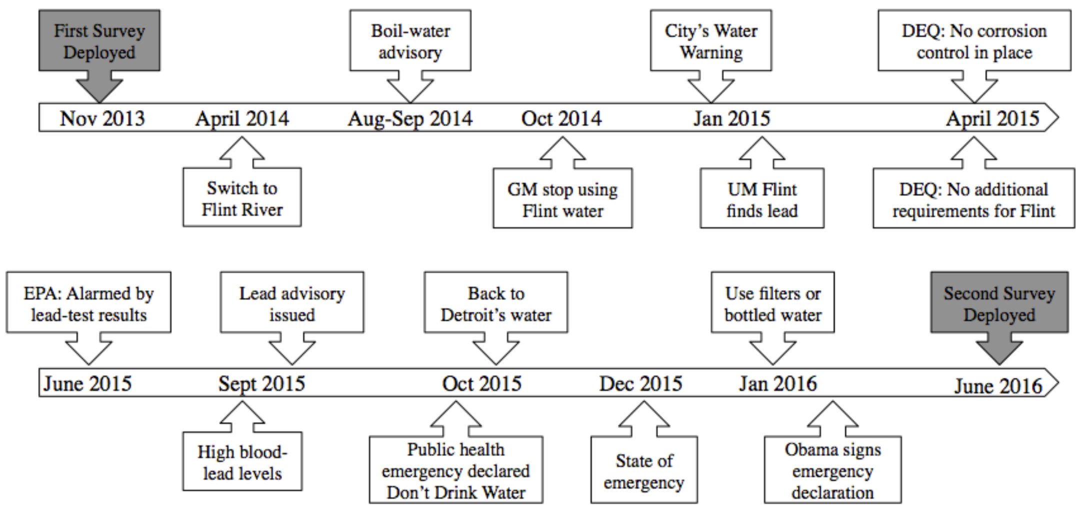

Figure 3.1. Timeline of the FWC and survey deployment (adapted from Dixon 2016)

3.2. STATISTICAL MODELING

The methodology used in this study is summarized in Fig. 3.2. Multiple binary statistical models were developed to identify the model with the best fit. The first dependent parameter, *Trust,* is true if an individual trusts his/her water provider to make decisions in his/her best interest and the second parameter, *Active,* is true if one would like to partake in participatory processes of the local utilities. For each dependent parameter, models were developed using data from the two separate surveys (i.e., 2013 and 2016), with an additional model combining the datasets into a single 2013/2016 dataset. To assess if public

Active and *Trust* have changed from 2013 to 2016, a Likelihood Ratio Test (LRT) was conducted evaluating the independence of the two data sets (i.e. 2013 and 2016). To select the best-fit models for each 2013, 2016 and 2013/2016, values from the Log-Likelihood (LL) and Akaike Information Criterion (AIC) were used.

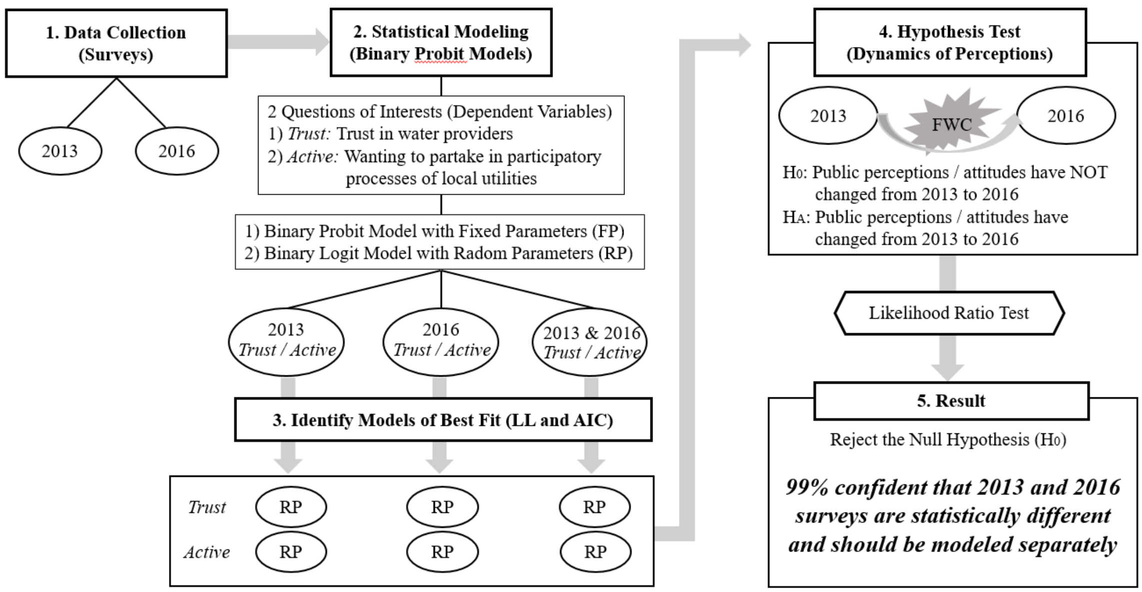

Figure 3.2. Methodology

3.2.1 Binary probit model

A binary model estimates the probability that a dependent parameter takes two discrete outcomes (e.g., zero or one) depending on conditions of independent parameters (Horowitz and Savin, 2001).

$$P_n(Trust) = \Phi(\frac{\beta_{Trust}\mathrm{X}_{Trust,n}}{\sigma}) \qquad \text{Eq.3.1}$$

$P_n(Trust)$ is the probability that respondents trust their water provider for observation n, where Phi (Φ) is the standardized cumulative normal distribution, β_{Trust} is a vector of estimable parameters for outcome *Trust*, and $X_{Trust,n}$ is a vector of the observable characteristics that determines the outcome for observation n (Washington et al., 2010). The same approach is applied for binary probit models of the dependent parameter, *Active*.

3.2.2. Probit model with random parameters

By letting $T_{Trust,n}$ be a linear function that estimates the discrete outcome, *Trust,* for observation n and having a disturbance term, $\varepsilon_{Trust,n}$, the equation can be expressed as below.

$$T_{Trust,n} = \beta_{Trust} X_{Trust,n} + \varepsilon_{Trust,n} \qquad \text{Eq.3.2}$$

To account for unobserved heterogeneity and allow parameter values to vary across the population according to some pre-specified distribution function, random parameters are used for the model (Washington et al., 2010). The probability of observation n having the outcome of *Trust* for the random parameters model, $P^{r}_{Trust}(n)$ can be defined as

$$P^{r}_{Trust}(n) = \int_X P_n(Trust) f(\beta|\varphi) d\beta \qquad \text{Eq.3.3}$$

where f(β | φ) dβ is the density function of β and φ is a vector of parameters of that density function (mean and variance) (Washington et al., 2010). Similarly, as above, modeling *Active* follows the same method.

3.2.3. Best-fit model selection

Selecting the model with best-fit is a process of balancing a tradeoff between being biased versus over fitting (Burnham and Anderson, 2004). A model with too few parameters can be biased, whereas too many parameters can make a model over fit

(Burnham and Anderson, 2004). AIC was developed by Akaike in 1970s by recognizing a relationship between Kullback-Leibler (K-L) information and likelihood theory (Burnham and Anderson, 2004). The equation of AIC is:

$$\text{AIC} = -2\text{Log}(f(y|data))+2\text{K} \qquad \text{Eq.3.4}$$

which consists of the maximized log-likelihood function, Log(f(y | data)) and the asymptotic bias correction term, K (Burnham and Anderson, 2004). Since AIC value represents the amount of information lost when using a model to represent the data, the model with the lowest AIC was considered as best-fit (Anderson, 2002).

3.2.4. Marginal effects (Partial effects)

Statistical significance can be determined by measuring marginal effects (Washington at el., 2010). Marginal effects are the change in a dependent parameter when an independent parameter changes from 0 to 1 (for binary parameters) or there is a one-unit change in the independent parameter, while all other parameters remain constant (Cameron and Trivedi, 2009). Marginal effect (δ_i) for an independent parameter (X_i) on a dependent parameter (*Trust*) can be calculated as follows.

$$\delta_i = P(Trust = 1|X_i = 1) - P(Trust = 1|X_i = 0) \qquad \text{Eq.3.5}$$

For this particular case, the marginal effect is an indicator of how influential an individual parameter (X_i) is in on *Trust*. Equation 3.5 applies to *Active*, as well.

3.2.5. Likelihood ratio test

Hypothesis tests are effective in assessing whether the dependent parameters were different between two or more groups of data sets (Washington at el., 2010). To perform a hypothesis test, two competing statistical hypotheses are developed: the null hypothesis, H_0, and the alternative hypothesis, H_a. The null hypothesis is that there has not been a change in level of trust or whether an individual would like to participate in decision making processes from 2013 to 2016, therefore the data set should be modeled together. On the other hand, the alternate, H_a is that there has been a change, so that the data set should be modeled separately.

To test the null hypothesis, the p-value was calculated using Chi-square (χ^2) value and Degree of Freedom (DOF). The p-value is a measurement of the strength of evidence against the null hypothesis (Washington et al., 2010). Let β_T, β_{2013}, and β_{2016} be the maximum value of likelihood of data of 2013 and 2016 combined, 2013 only, and 2016 only, respectively. Then the ratio $\lambda = \beta_T/(\beta_{2013}\beta_{2016})$ explains how likely the assumption is true (Natrella, 2010). The larger λ indicates higher possibility and smaller λ indicates lower possibility (Natrella, 2010).

$$\begin{aligned}\chi^2 &= -2\ln\lambda = -2\ln[\beta_T/(\beta_{2013}\beta_{2016})] \\ &= -2\,[LL_{\beta_T} - LL_{\beta_{2013}} - LL_{\beta_{2016}}]\end{aligned} \qquad \text{Eq.3.6}$$

At the same time, let dof_{2013}, dof_{2016}, and dof_T be the degree of freedom of the probit models with random parameters from data of 2013 only, 2016 only, and 2013 and 2016 combined, respectively. The DOF value for Chi-square test is:

$$DOF = dof_{2013} + dof_{2016} - dof_T \qquad \text{Eq.3.7}$$

Chapter 4. Descriptive Statistics

In total, 455 and 451 valid surveys were collected from 21 US shrinking cities in 2013 and 2016, respectively. In 2013, 48% were over 50 years old, 60% were female, and 47% were married. In 2016, 16% were over 50 years old, 69% were female, and 45% were married. In both 2013 and 2016, a majority of respondents grew up or were born in cities where they are currently residing, hold at most a college degree, and have average individual annual income less than $75,000. Additionally, the majority of respondents were employed for wages, self-employed or retired. Considering household characteristics, the households surveyed had an average of 2.6 (3.1) people, and 1.5 (1.7) cars.

Parameters	**2013**		**2016**	
	Min/ Max	**Mean (Std. Dev.)**	**Min/ Max**	**Mean (Std. Dev.)**
INDIVIDUAL CHARACTERISTICS				
Age				
18-25 years old (1 if 18-25 years old, otherwise 0)	0/1	0.0921 (0.2895)	0/1	0.2352 (0.4246)
26-35 years old (1 if 26-35 years old, otherwise 0)	0/1	0.1978 (0.3988)	0/1	0.3744 (0.4845)
36-50 years old (1 if 36-50 years old, otherwise 0)	0/1	0.2337 (0.4237)	0/1	0.2329 (0.4231)
over 50 years old (1 if over 50 years old, otherwise 0)	0/1	0.4764 (0.5000)	0/1	0.1575 (0.3647)
Gender				
Gender (1 if female, otherwise 0)	0/1	0.5955 (0.4913)	0/1	0.6826 (0.4660)
Marital Status				
Single (1 if single, otherwise 0)	0/1	0.3618 (0.4811)	0/1	0.4315 (0.4959)
Married (1 if married, otherwise 0)	0/1	0.4697 (0.4996)	0/1	0.4543 (0.4985)
Hometown				
Grew up in an urban area (1 if true, otherwise 0)	0/1	0.3891 (0.4881)	0/1	0.3790 (0.4857)
Grew up in a Suburban area (1 if true, otherwise 0)	0/1	0.5294 (0.4997)	0/1	0.4566 (0.4987)

Table 4.1. Respondent demographic information (2013 and 2016)

Parameters	2013 Min/Max	2013 Mean (Std. Dev.)	2016 Min/Max	2016 Mean (Std. Dev.)
Grew up in a Rural area (1 if true, otherwise 0)	0/1	0.0814 (0.2738)	0/1	0.1644 (0.3710)
Grew up where currently living (1 if true, otherwise 0)	0/1	0.6022 (0.4900)	0/1	0.5388 (0.4991)
Born where currently living (1 if true, otherwise 0)	0/1	0.5730 (0.4951)	0/1	0.4520 (0.4983)
Number of years you lived in your city (years)	0/80	33.1846 (20.6603)	0/66	18.0900 (14.7572)
Education				
Highest level of education (1 if some high school, otherwise 0)	0/1	0.0292 (0.1686)	0/1	0.0251 (0.1567)
Highest level of education (1 if high school diploma, otherwise 0)	0/1	0.3506 (0.4777)	0/1	0.3288 (0.4703)
Highest level of education (1 if technical college degree, otherwise 0)	0/1	0.1596 (0.3666)	0/1	0.1256 (0.3317)
Highest level of education (1 if college degree, otherwise 0)	0/1	0.3326 (0.4717)	0/1	0.3950 (0.4894)
Highest level of education (1 if post graduate, otherwise 0)	0/1	0.1281 (0.3346)	0/1	0.1256 (0.3317)
Individual Income				
No Income (1 if respondent has no income, otherwise 0)	0/1	0.0854 (0.2798)	0/1	0.0365 (0.1878)
Under $19,999 (1 if income is less than $19,999, otherwise 0)	0/1	0.2427 (0.4292)	0/1	0.1872 (0.3905)
$20,000-$34,999 (1 if income is between $20,000-$34,999, otherwise 0)	0/1	0.2382 (0.4265)	0/1	0.2466 (0.4315)
$35,000-$49,999 (1 if income is between $35,000-$49,999, otherwise 0)	0/1	0.1663 (0.3728)	0/1	0.1872 (0.3905)
$50,000-$74,999 (1 if income is between $50,000-$74,999, otherwise 0)	0/1	0.1596 (0.3666)	0/1	0.1804 (0.3849)
$75,000-$99,999 (1 if income is between $75,000-$99,999, otherwise 0)	0/1	0.0674 (0.2510)	0/1	0.0845 (0.2784)
$100,000 and above (1 if income is greater than $100,000, otherwise 0)	0/1	0.0404 (0.1972)	0/1	0.0776 (0.2679)
Employment Status				
Employed for wages or salary (1 if true, otherwise 0)	0/1	0.4045 (0.4913)	0/1	0.6210 (0.4857)
Self-employed (1 if true, otherwise 0)	0/1	0.0899 (0.2863)	0/1	0.0685 (0.2529)
Out of work (1 if true, otherwise 0)	0/1	0.0651 (0.2471)	0/1	0.0548 (0.2278)
Homemaker (1 if true, otherwise 0)	0/1	0.1281 (0.3346)	0/1	0.0800 (0.2715)
Student (1 if true, otherwise 0)	0/1	0.0674 (0.2510)	0/1	0.0868 (0.2818)

Table 4.1., cont.

Parameters	2013		2016	
	Min/ Max	Mean (Std. Dev.)	Min/ Max	Mean (Std. Dev.)
Retired (1 if true, otherwise 0)	0/1	0.2180 (0.4133)	0/1	0.0548 (0.2278)
Unable to work (1 if true, otherwise 0)	0/1	0.0899 (0.2863)	0/1	0.0342 (0.1821)
Responsibility for Utility bill				
Responsible for water bill (1 if true, otherwise 0)	0/1	0.7416 (0.4383)	0/1	0.8881 (0.3156)
HOUSEHOLD CHARACTERISTICS				
Family member				
Number of children under the age of 18 living in household (youth)	0/4	0.5551 (0.9127)	0/5	0.9041 (0.1560)
Number of children under the age of 5 living in household (children)	0/3	0.1685 (0.4894)	0/3	0.2867 (0.6124)
Number of people in household (people)	0/9	2.5820 (1.3526)	0/40	3.0731 (2.3099)
Cars				
Number of Cars in Household (cars)	0/8	1.5056 (0.9291)	0/6	1.6751 (0.8958)
Household Ownership				
Household ownership (1 if own home, otherwise 0)	0/1	0.7107 (0.4540)	0/1	0.6530 (0.4766)
Household ownership (1 if first home owned, otherwise 0)	0/1	0.5263 (0.5001)	0/1	0.4361 (0.4965)
Length of time you owned (years)	0/60	16.1930 (13.8575)	0/45	8.4542 (8.1574)
Household Income				
No Income (1 if respondent has no income, otherwise 0)	0/1	0.0360 (0.1864)	0/1	0.0228 (0.1495)
Under $19,999 (1 if income is less than $19,999, otherwise 0)	0/1	0.1551 (0.3624)	0/1	0.1142 (0.3184)
$20,000-$34,999 (1 if income is between $20,000-$34,999, otherwise 0)	0/1	0.1888 (0.3918)	0/1	0.1735 (0.3791)
$35,000-$49,999 (1 if income is between $35,000-$49,999, otherwise 0)	0/1	0.1640 (0.3707)	0/1	0.2100 (0.4078)
$50,000-$74,999 (1 if income is between $50,000-$74,999, otherwise 0)	0/1	0.2337 (0.4237)	0/1	0.2169 (0.4126)
$75,000-$99,999 (1 if income is between $75,000-$99,999, otherwise 0)	0/1	0.1124 (0.3161)	0/1	0.1347 (0.3418)
$100,000 and above (1 if income is greater than $100,000, otherwise 0)	0/1	0.1101 (0.3134)	0/1	0.1279 (0.3343)

Table 4.1., cont.

In addition to the respondent demographics, the survey contained public perception questions assessing perceptions toward water infrastructure. Questions were posed on a Likert scale from strongly disagree to strongly agree (i.e. 1-5) with an additional option for "I don't know." One question of interest posed (modeled in this study), asked whether individuals trust his/her water provider to make appropriate decisions in his/her best interests (see Fig. 4.1). The aggregated survey data for 2013 (2016) indicated that 4% (6%) of respondents strongly disagreed, 14% (14%) disagreed, 39% (25%) stayed neutral, 23% (34%) agreed, and 12% (18%) strongly agreed with the statement regarding *Trust*, and 8% (3%) chose "I don't know." Between 2013 and 2016, there was a noticeable decrease in the population who identified as neutral (decrease of 14%) or I don't know (decrease of 5%) in the context of *Trust*. Interestingly, the percentage of individuals who agree, and strongly agree with the statement regarding *Trust* increased between 6% and 11%, respectively. It may be inferred that individuals in the general public in 2016 are more likely to take a position rather than being indifferent as compared to 2013 who exhibited a greater degree of decision paralysis. In Fig. 4.1 (b), responses were collapsed to agree, disagree, and do not know. Agree contains strongly agree, agree, and neutral. Disagree contains disagree and strongly disagree.

The second question modeled in this study is whether respondents would like to actively partake in the decision making process of their local water utilities (see Fig. 4.2). The question was formed on the same Likert scale as *Trust*. The survey data revealed for 2013 (2016) that 4% (4%) of respondents strongly disagreed, 14% (9%) disagreed, 39% (28%) stayed neutral, 24% (31%) agreed, 12% (23%) strongly agreed with the statement, and 8% (5%) chose "I don't know." Between 2013 and 2016, there was a decrease in the population who identified as neutral or disagree of 5% and 11%, respectively, when asked about partaking in participatory processes with utility. Whereas, the percentage of individuals who agreed and strongly agreed increased by 7% and 11%, respectively. This shift in aggregate numbers indicates that individuals in the general public in 2016 were more likely to want to partake in the utility decision making process in 2016 as compared to 2013. Fig. 4.2 (b) was collapsed similarly to Fig.4.1 (b).

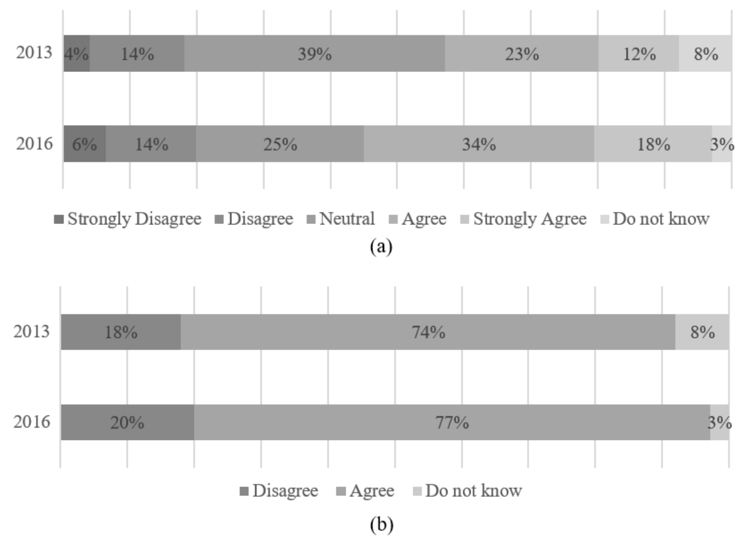

Figure 4.1. Trust in water provider to make appropriate decisions in respondent's best interest: (a) Expanded and (b) Collapsed

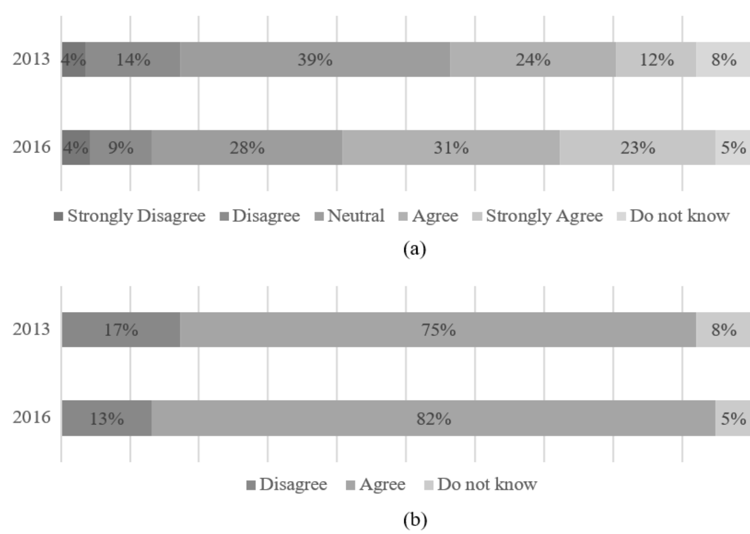

Figure 4.2. Want to partake in participatory process with local utilities: (a) Expanded and (b) Collapsed

Another perception question that was posed on a Likert scale from dramatically decreased to dramatically increased was the perceived change in quality of water service in the past 10 years (see Fig. 4.3). In 2013, over 60% of respondents said there was no change in the quality of their water providers, and approximately 10% of population specified that the quality has dramatically increased or increased in past 10 years. In 2013, only approximately 20% said the quality has decreased or dramatically decreased. In 2016, the percentage of the population who thought the quality of their water provider did not change in past 10 years has significantly reduced by half. At the same time, percentage of individuals who thought the quality has slightly improved, slightly decreased, and dramatically decreased have doubled in 2016 compared to 2013. Interestingly, not only the percentage of residents who replied that the quality of their water service have decreased, but at the same time those who replied that the quality has improved also increased. It can be conjectured that increased nationwide media attentions on water infrastructures due to the FWC have dramatically influenced the public to pay more attention on the quality of their water services.

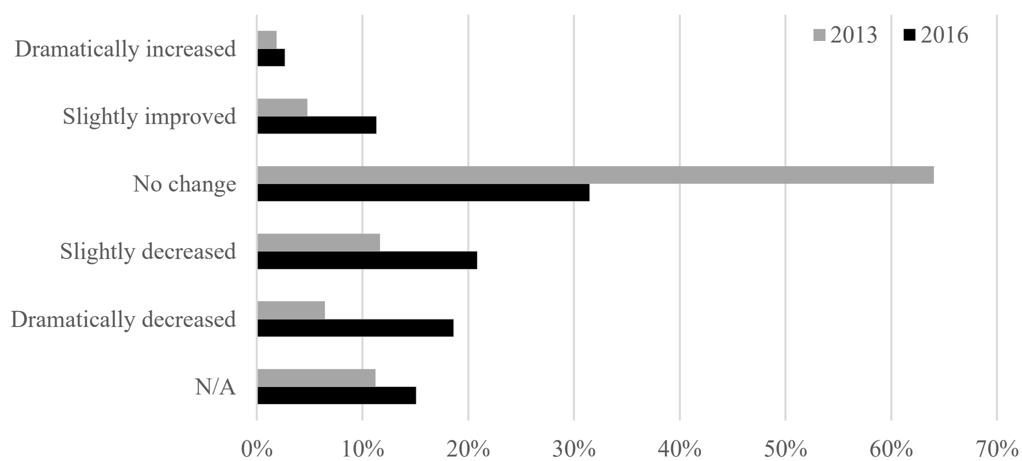

Figure 4.3. Change of service quality from water provider in the past 10 years

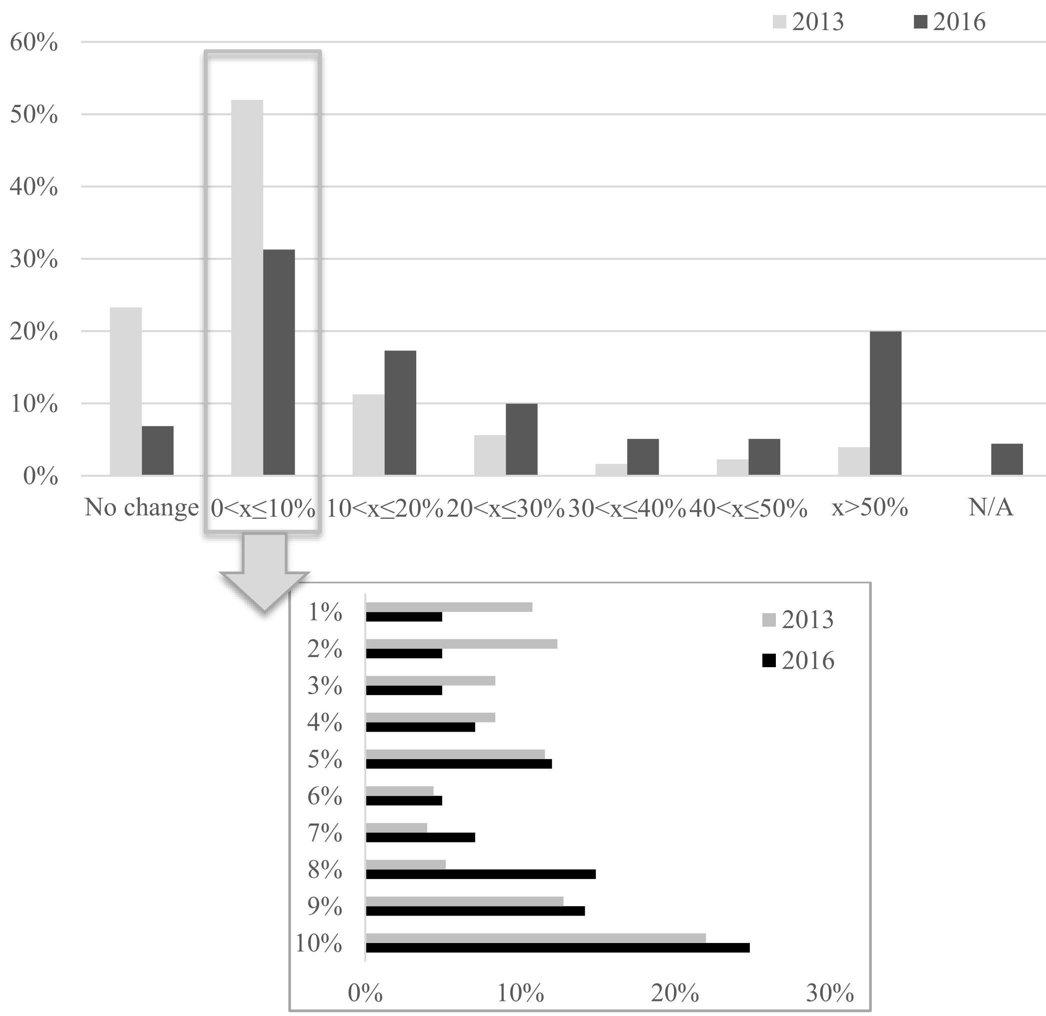

Figure 4.4. How much more (%) individuals are willing to pay for improved reliability of water service

Respondents were also asked how much more they are willing to pay for improved reliability of the water service as a percentage. For instance, an individual who indicated a 100% is willing to pay double for improved reliability of his/her water service. As seen in Fig. 4.4, over 75% of the respondents were willing to pay increased rates, and over 50% of respondents fell within the range of being willing to pay between 0% to 10% more. However, in 2016, over 90% of respondents were willing to pay more for improved reliability. Additionally, more than 50% of respondents were willing to pay more than 10% as compare to 2013. Interestingly, 20% of the populations said they were ready to pay more than 50% increased utility bills in 2016 for improved quality. The surveyed cities are fiscally strained with poverty rates often double and occasionally triple the national average (Faust et al., 2016). In spite the fiscal constraints, the willingness to pay more has noticeably increased in 2016 compared to 2013 if there is a measurably improvement in service.

Chapter 5. Results and Interpretations

This Chapter presents the: (1) likelihood ratio test assessing whether the two surveys' data are statistically different, and (2) statistical modeling of an individual's trust in his/her water provider and wanting to partake in participatory processes of local utilities (Tables 5.1 – 5.6). Tables 5.3 and 5.6 illustrate shifts of parameters between 2013 and 2016.

5.1. LIKELIHOOD RATIO TEST RESULTS

The LRT was conducted to evaluate the alternative hypothesis (that two surveys taken in 2013 and 2016 are statistically different) against the null hypothesis (that 2013/2016 are not statistically different). The χ^2 statistic that provides confidence level of rejecting the null hypothesis and degree of freedom (*dof*) was calculated using the Eq.3.6 and 3.7. For *Trust* model, χ^2 statistic is 21.16. With 9 degrees of freedom, indicating a 99.8% confidence that the 2013 and 2016 survey data for *Trust* are statistically different, and should be modeled separately. Similarly, for the *Active* models, the χ^2 statistic is 17.44, with 1 degree of freedom, indicating a more than 99.9% confidence that the 2013 and 2016 data should be separately modeled.

5.2. MODEL RESULTS FOR TRUST IN WATER PROVIDERS

Tables 5.1 and 5.2 shows the results of model that estimates individual's trust toward his/her water providers. Negative parameter values indicate a decreased likelihood in *Trust*, while positive values indicate an increased likelihood in *Trust*. Table 5.3 summarizes shifts in significant parameters impacting *Trust* between 2013 and 2016. "N/S" in Table 5.3 represents "Non-Significant" indicating that the corresponding parameter was not statistically significant in the respective model.

Independent Parameter	Parameter (t-statistic)	St.Deviation (t-statistic)	Marginal Effects
Fixed parameters			
Constant	2.08 (6.19)	*fixed*	
Employment status (1 if self-employed, otherwise 0)	-1.23 (-3.57)	*fixed*	-.01660
Gender (1 if female, otherwise 0)	-0.60 (-2.42)	*fixed*	-.00805
Flint, Michigan indicator (1 if currently residing in Flint, otherwise 0)	-1.08 (-2.06)	*fixed*	-.01450
Cincinnati, Ohio indicator (1 if currently residing in Cincinnati, otherwise 0)	1.27 (2.33)	*fixed*	.01712
Cleveland, Ohio indicator (1 if currently residing in Cleveland, otherwise 0)	-0.72 (-2.05)	*fixed*	-.00972
New York state indicator (1 if currently residing in New York, otherwise 0)	0.66 (2.08)	*fixed*	.00887
Random parameters			
Home ownership (1 if home owned, otherwise 0)	-0.85 (-3.22)	0.72 (4.88)	-.01145
Hometown (1 if grew up in a suburban area, otherwise 0)	0.88 (3.00)	2.71 (7.34)	.01182
Age (1 if between 26 and 35, otherwise 0)	2.32 (3.56)	5.33 (5.69)	.03123
Number of cars (1 if household owns more than one cars)	0.97 (3.11)	2.50 (6.90)	.01307
Baltimore, Maryland indicator (1 if currently residing in Baltimore, otherwise 0)	2.15 (1.70)	4.43 (2.69)	.02896
Log likelihood at convergence	-222.354		
AIC	478.7		
Number of observation	445		

Table 5.1: Statistically significant parameters influencing trust in water provider (2013) (all random parameters are normally distributed)

Independent Parameter	Parameter (t-statistic)	St. Deviation (t-statistic)	Marginal Effects
Fixed parameters			
Constant		*fixed*	
Age (1 if between 18 and 25, otherwise 0)	0.58 (2.23)	*fixed*	.02415
Income (1 if more than $75,000, otherwise 0)	1.78 (3.66)	*fixed*	.06968
Location born and grew (1 if born and raised in city currently residing in, otherwise 0)	0.48 (2.30)	*fixed*	.01916
Michigan state indicator (1 if currently residing in Michigan, otherwise 0)	-1.50 (-5.42)	*fixed*	-.06201
Number of cars (1 if household owns more than two cars)	-0.95 (-3.20)	*fixed*	-.03912
Home ownership (1 if home owned, otherwise 0)	0.60 (2.51)	*fixed*	.02523
Random parameters			
Education (1 if have college degree or post graduate degree, otherwise 0)	0.98 (3.21)	2.85 (7.31)	.03750
Marital status (1 if married, otherwise 0)	1.04 (3.77)	1.39 (5.71)	.04646
Employment status (1 if self-employed, otherwise 0)	-0.22 (-0.47)	2.56 (3.61)	-.00514
Log likelihood at convergence	*-195.64*		
AIC	*417.3*		
Number of observation	*438*		

Table 5.2. Statistically significant parameters influencing trust in water provider (2016) (all random parameters are normally distributed)

Tables 5.1 and 5.2 show the results of the models estimating parameters influencing the likelihood an individual trusts his/her water provider in 2013 and 2016, respectively. In regard to geographic parameters in 2013, interestingly, Cincinnati and Cleveland, Ohio were observed to have opposite impacts toward the likelihood of trusting the local water providers (see Tables 5.1 and 5.2). Although the two cities are both located in Ohio state, residents in Cincinnati were more likely to trust their water providers, while residents in Cleveland were less likely to trust their water providers (Tables 5.1 and 5.2). More interestingly, both city parameters were not-significant in the 2016 prediction model (Table 5.3), indicating a change in the geographic significance for these cities. Statistically significant geographic parameters may be a result of local interactions and relationships between the residents and utilities. During this time frame, the shift in significance may be capturing changes in local utility-resident interactions.

Residents in Flint, Michigan were observed to have a decreased likelihood of trusting their water providers in 2013 (Table 5.1). Unsurprisingly, however, in 2016, respondents residing in not only Flint, but shrinking cities throughout Michigan state were less likely to trust their water utilities (Table 5.2). This may reflect that residents in surrounding cities nearby the FWC had heightened levels of concern toward their water service. After the advisory not to drink tap water, bottled water became a vital necessity for water needs, from consumption to bathing. Residents in Flint started to consume bottled water for drinking as well as washing dishes, cooking, and washing hair (IBWA, 2016). According to CNN, one household of three people in Flint is using 151 bottles of water per day (Zdanowicz, 2016). In response to increased demands in bottled water in the City of Flint, a number of companies, organizations, and celebrities have donated bottled water to Flint to support the residents to be safe from contaminated water (Bever, 2016). This increased media attention was not only local, but nationwide. However, it can be presumed that Michigan media sources focused on the crisis to an even greater degree as it occurred within Michigan state.

In 2013, it was also observed that residents in New York state were more likely to trust their water providers (Table 5.1). In addition, 68.6% of residents in Baltimore, Maryland were more likely to trust their water providers in 2013, while 31.4% were not (Table 5.1), exhibiting heterogeneous across the population captured in the significant random parameter. However, both parameters were revealed as non-significant in predicting the likelihood of trust in water providers in 2016 (Table 5.3).

The overall findings from geographic parameters show that residents in selected locations, specially cities or states that are close to Flint (no other cities outside of Michigan were significant predictors in 2016) where the FWC has occurred, tend to have decreased likelihood of trusting their water providers in 2016, possibly due to the proximity of the FWC.

Significant demographic parameters influencing the likelihood of individuals' trust in his/her water include age, gender, marital status, individual annual income, home ownership, education, employment status, location born and grew, number the of cars in the household (Tables 5.4 and 5.5). In 2013, 66.8% of respondents with ages between 26 and 35 had an increased likelihood of trusting their water providers, while 33.2% had a decreased likelihood of trusting their water providers (Table 5.1). However, as shown in Table 5.3, the parameter indicating respondents with ages within this range (i.e., between 26 and 35) was not significant in the model in 2016. On the contrary, respondents who are between 18 and 25 had an increased likelihood of trusting their water providers in 2016 (Table 5.2). This may be because younger age groups are more accessible through social media (e.g., Facebook, Instagram, Blog) by local water utilities, facilitating improved communication with their customers between 18 and 25 years of age as compared to those between 26 and 35, and warrants further studies on utility-customer relationships across age groups.

In addition, respondents who have relatively high income (individual annual income more than $75,000) were more likely to trust their water providers in 2016, while this parameter was observed as non-significant in 2013. Similarly, parameters capturing home ownership, had a positive shift in trusting the water providers between 2013 and 2016. 88.1% of respondents who owned their homes had a decreased likelihood of trusting their water providers in 2013 (Table 5.1), while 11.9% did not. Whereas, as shown in Table 5.2, those who own houses were more likely to trust their water providers in 2016.

Generally, the parameters representing the number of cars in a household is an indicator of wealth, i.e., more cars often correlate with higher wealth in the household. 65.1% of individuals whose household owns more than one car were more likely to trust their water providers in 2013 (Table 5.1), while 34.9% were not. On the other hand, individuals whose households have more than two cars were less likely to trust the local utilities in 2016 (Table 5.2), capturing temporal changes in perceptions. This is seemingly contradictory to the aforementioned income and home ownership variables. However, this parameter indicating number of cars in the household may not capture the wealth in this study as households with two cars do not always indicate wealthy households.

Parameters that were related to the hometown were statistically significant in trusting their water providers. In 2013, 62.7% of respondents who grew up in a suburban area were more likely to trust the local water utilities, while 37.3% were not (Table 5.1). This may indicate different relationships between utilities serving and customers in suburban areas. The parameter was not significant in 2016 (Table 5.3). Instead, a parameter capturing whether individuals were born and raised in the city where they currently reside in became statistically significant in 2016 (Table 5.3). Individuals who were born and raised in the city they currently reside in were observed to have more likelihood of trusting their water providers in 2016 (Table 5.2). This is possibly corresponding with the finding from Humphries and Wilding (2004) that long-term collaborative relationships are correlated with trust between two parties (utility providers / cities and customers).

Moreover, parameters that explain the marital status and level of education were significant in influencing trust in the local water providers in 2016 (Table 5.2). 77.3% of individuals who were married were more likely to trust their water providers in 2016, while 22.7% were not (Table 5.2). Similarly, 63.5% of respondents who have college degree or post graduate degree had an increased likelihood of trusting their water providers, while

36.5% did not (Table 5.2). In many instance, marriages capture dual-income households, which are often higher household incomes than single-person household incomes. Additionally, college completion rates are higher for students in wealthy families, compared to low-income students, and the median earnings of Bachelor's degree holders were 74% higher than those with just high school diploma in 2009 (Carnevale et al., 2011; Rauscher and Elliott, 2014). Therefore, the positive significance of marital status and education may be further indicators of wealth increasing the likelihood of trusting water providers in 2016.

The parameter identifying the self-employment was the only demographic parameter that was observed to be statistically significant in both 2013 and 2016. Individuals who were self-employed were observed to have less likelihood to trust their water providers in both years (Tables 5.1 and 5.2).

Independent Parameter	2013	2016
Constant	+	*N/S*
Age (1 if between 18 and 25, otherwise 0)	*N/S*	+
Age (1 if between 26 and 35, otherwise 0)	+	*N/S*
Gender (1 if female, otherwise 0)	-	*N/S*
Marital status (1 if married, otherwise 0)	*N/S*	+
Income (1 if more than $75,000, otherwise 0)	*N/S*	+
Home ownership (1 if home owned, otherwise 0)	**-**	**+**
Education (1 if have college degree or post graduate degree, otherwise 0)	*N/S*	+
Employment status (1 if self-employed, otherwise 0)	-	-
Hometown (1 if grew up in a suburban area, otherwise 0)	+	*N/S*
Location born and grew (1 if born and raised in city currently residing in, otherwise 0)	*N/S*	+
Number of cars (1 if household owns more than two cars)	**+**	**-**
Flint, Michigan indicator (1 if currently residing in Dayton, otherwise 0)	-	*N/S*
Cincinnati, Ohio indicator (1 if currently residing in Dayton, otherwise 0)	+	*N/S*
Cleveland, Ohio indicator (1 if currently residing in Dayton, otherwise 0)	-	*N/S*
New York state indicator (1 if currently residing in Michigan, otherwise 0)	+	*N/S*
Michigan state indicator (1 if currently residing in Michigan, otherwise 0)	*N/S*	-
Baltimore, Maryland indicator (1 if currently residing in Dayton, otherwise 0)	+	*N/S*

Table 5.3. Summary of parameters in the model of likelihood of trusting the water provider (bold indicates parameters that shifted from having positive to negative prediction or vice versa between 2013 and 2016)

5.3. MODEL RESULTS FOR WANTING TO PARTAKE IN PARTICIPATORY PROCESSES OF LOCAL UTILITIES

Tables 5.4 and 5.5 show the results of models estimating whether an individual would like to partake in participatory processes of local utilities. The negative values on the parameter (t-statistic) column indicate decreased likelihood of *Active*, otherwise states as a decreased likelihood of wanting to partake in participatory processes with local utilities, while a positive values indicate increased likelihood. Table 5.6 demonstrates changes in parameters influencing *Active* between 2013 and 2016. "N/S" on Table 5.6

represents “Non-Significant” indicating that corresponding parameter revealed to be not statistically significant in the respective model.

Independent Parameter	Parameter (t-statistic)	St. Deviation (t-statistic)	Marginal Effects
Fixed parameters			
Constant	0.61 (3.70)	*fixed*	
Age (1 if between 36 and 50, otherwise 0)	0.90 (3.43)	*fixed*	.02856
Employment status (1 if self-employed, otherwise 0)	1.87 (2.86)	*fixed*	.05960
Education (1 if have college degree or post graduate degree, otherwise 0)	-0.54 (-2.62)	*fixed*	-.01704
Birmingham, Alabama indicator (1 if currently residing in Birmingham, otherwise 0)	2.05 (2.21)	*fixed*	.06508
Buffalo, New York indicator (1 if currently residing in Buffalo, otherwise 0)	1.38 (2.71)	*fixed*	.04388
Michigan state indicator (1 if currently residing in Michigan, otherwise 0)	-0.68 (-1.93)	*fixed*	-.02162
Random parameters			
Utility bill (1 if responsible for utility bill payment, otherwise 0)	1.83 (5.55)	2.42 (7.61)	.05821
Log likelihood at convergence	-194.72		
AIC	407.4		
Number of observation	445		

Table 5.4. Statistically significant parameters influencing the likelihood of wanting to partake in participatory process with local utilities (2013) (all random parameters are normally distributed)

Independent Parameter	Parameter (t-statistic)	St.Deviation (t-statistic)	Marginal Effects
Fixed parameters			
Constant	1.16 (9.76)	*fixed*	
Age (1 if above 50, otherwise 0)	-0.48 (-2.16)	*fixed*	-.01953
Employment status (1 if student, otherwise 0)	-0.68 (-2.62)	*fixed*	-.02755
Children present in household (1 if kids under age of 5 live in household, otherwise 0)	0.86 (2.61)	*fixed*	.03456
Birmingham, Alabama indicator (1 if currently residing in Birmingham, otherwise 0)	-0.47 (-1.82)	*fixed*	-.01906
Random parameters			
Ohio state indicator (1 if currently residing in Ohio, otherwise 0)	4.02 (2.71)	4.24 (3.35)	.15855
Log likelihood at convergence	-159.11		
AIC	332.2		
Number of observation	438		

Table 5.5. Statistically significant parameters influencing the likelihood of wanting to partake in participatory process with local utilities (2016) (all random parameters are normally distributed)

Independent Parameter	2013	2016
Fixed parameters		
Constant	+	+
Age (1 if between 36 and 50, otherwise 0)	+	*N/A*
Age (1 if above 50, otherwise 0)	*N/A*	-
Employment status (1 if self-employed, otherwise 0)	+	*N/A*
Employment status (1 if student, otherwise 0)	*N/A*	-
Education (1 if have college degree or post graduate degree, otherwise 0)	-	*N/A*
Children present in household (1 if kids under age of 5 live in household, otherwise 0)	*N/A*	+
Birmingham, Alabama indicator (1 if currently residing in Birmingham, otherwise 0)	+	-
Buffalo, New York indicator (1 if currently residing in Buffalo, otherwise 0)	+	*N/A*
Michigan state indicator (1 if currently residing in Michigan, otherwise 0)	-	*N/A*
Random parameters		
Utility bill (1 if responsible for utility bill payment, otherwise 0)	+	*N/A*
Ohio state indicator (1 if currently residing in Ohio, otherwise 0)	*N/A*	+

Table 5.6. Summary of parameters in the model wanting to partake in participatory process with local utilities

Tables 5.4 and 5.5 show the results of the models estimating if an individual would like to partake in participatory processes with his/her local utilities in 2013 and 2016, respectively. The models indicate that geographic parameters were more prevalent to be significant than other demographic parameters in wanting to be involved in decision making processes both in 2013 and 2016. This may imply that the desire to be in part of participatory processes are more significantly driven by localized factors than an individual's characteristics. Furthermore, all geographic parameters, except the Ohio state parameter in 2016 model (Table 5.5), were fixed, indicating that most geographic parameters had homogeneous impact on likelihood of wanting to partake in participatory process and did not vary across the local populations.

With regard to geographic parameter findings in 2013, residents in Birmingham, Alabama, and Buffalo, New York were more likely to want to partake in participatory process of local utilities, while those who live in Michigan state were less likely to want to be involved in decision making processes (Table 5.4). The differences across geographic locations may due to different factors, such as economic conditions, political or social environments, and relationship between utilities and customers. For instance, it is logical that increased accessibility of local utilities to the public and active, consistent communication with customers may provide circumstances in which the public can share information and provide feedback that may impact decision making processes of local utilities.

Interestingly, in 2016 (Table 5.5), individuals residing in Birmingham, Alabama were less likely to want to partake in participatory processes of local utilities, indicating that the public perceptions toward participatory processes, on average have shifted between 2013 and 2016 (Table 5.6). This shift in public perceptions of Birmingham, Alabama residents may be result of the water contamination issue that has been raised in 2016. In

May 2016, the Alabama Department of Public Health (ADPH) announced that the level of two manmade chemical pollutants (i.e. perfluorooctane sulfonate (PFOS) and perfluorooactanoic acid (PFOA)) in eight Alabama water systems were higher than standard level, newly set by the EPA (Yawn, 2016). An excessive exposure to PFOS and PFOA has been proved to cause health issues, such as cancer, liver effects, immune system disorders, and development effects of fetuses during pregnancy (Pillion, 2016).

In addition, the Michigan state parameter indicated that residents were to be less likely to want to partake in participatory process in 2013, was not significant in 2016 (Tables 5.4 and 5.6). In the case of Ohio state, the parameter was predicted to be not significant in 2013 (Table 5.6). Interestingly, in 2016, 82.9% of residents in Ohio's shrinking cities were more likely to want to be involved in decision making process, while 17.1% were not (Table 5.5), exhibiting heterogeneity across the population. Recalling the previous result that residents in Michigan state were less likely to trust their water providers (Table 5.2), whereas Ohio state parameter was not statistically significant in likelihood of trusting the water utilities in 2016 (Table 5.3), this may reflect customers' increased willingness to provide information and increased likeliness to perceive a relationship with the company when trust is established (Schoenbachler and Gordon, 2002). It is also possible that the Ohio State had effectively implemented strategies to facilitate communication between the public and local utilities.

On the other hand, the public perceptions have shifted in Buffalo, New York in which individuals residing in Buffalo, New York were more likely to want to partake in participatory processes with local utilities in 2013 (Table 5.4), as opposed to 2016 when the city indicator parameter was non-significant (Table 5.6). This shift of public perceptions may due to another water contamination issue arose in Hoosick Falls, New York. The concern about water quality has first came to attention in August 2014 by a resident (McKinley and Yee, 2016). In June 2015, the City contacted EPA with water contamination issues, which has found out that the amount of perfluorooctanoic acid (PFOA) that the Hoosick River contained was exceeding the safe level (EPA, 2016). The likely source of the chemical has been identified to be a local plant owned by Saint-Gobain Performance Plastics, a French company that manufactures Teflon-coated material (Assefa, 2016). After the warning in December, 2015 by the EPA, residents in Hoosick Falls began to use bottled water for drinking and cooking (McKinley and Yee, 2016).

The overall finding from geographic parameters is that select locations of shrinking cities are statistically significant in predicting the likelihood of residents wanting to partake in participatory processes of local water utilities. The management levels can identify the driving factors of active involvement of the public from case studying those locations.

Significant demographic parameters influencing the likelihood of individuals wanting to partake in decision making processes of local utilities include age, employment status, education, number of children in the household, and whether individual is responsible for utility bill payment (Tables 5.4 and 5.5). In 2013, respondents between 36 and 50 years of age were more likely to want to partake in participatory processes with local utilities (Table 5.4). However, the same age group (36-50 years old) were not significant in 2016 (Table 5.6). Respondents over 50 years old, were less likely to want to be involved in decision making process of water utility companies in 2016 (Table 5.5), while this was a non-significant parameter in 2013 (Table 5.6), demonstrating a temporal shift in perceptions. Public perceptions in both age groups (age between 36 and 50, and age over 50) demonstrated temporal dynamics in their perceptions toward participatory processes with local utilities. Furthermore, it should be noted as illustrated in Tables 5.4-5.6, no age group under 36 was predicted as statistically significant in predicting the likelihood of wanting to be involved in decision making processes.

In 2013, respondents who were self-employed were more likely to want to partake in participatory processes (Table 5.4). In addition, individuals who have college degree or post graduate degree were less likely to want to be involved (Table 5.4). Both parameters (self-employed and college degree as highest level of education) were no longer significant in 2016 (Table 5.6). However, in 2016, students were less likely to want to be involved in decision making processes of local utilities in 2016 (Table 5.5). This may because in general, students live in dormitory facilities that are managed by the University, apartment complexes where utility bills are included in their monthly rent, or houses that are owned by their parents.

Individuals who have children under age of 5 in their household were more likely to want to be involved in decision making processes in 2016 (Table 5.5). This may indicate that if young children are present in their household, residents pay more attention to local water that children daily use and drink. It may be explained by the fact that number of lawsuits been filed by parents whose children were found to have high blood lead level due to the FWC (Chambers, 2016). Specifically, Michigan Department of Education, Flint Community Schools, and the Genesee Intermediate School district have been sued for failing to provide safe facilities to children (Chambers, 2016). Another lawsuit against the City of Flint was filed by parents whose 2-year-old daughter was found to have high blood lead level after drinking the Flint water (Connor, 2016).

Lastly, 77.5% of residents who are responsible for paying their utility bill were more likely to want to partake in participatory processes in 2013, while 22.5% were less likely (Table 5.4). However, the parameter capturing responsibility of utility bill payment was statistically non-significant in 2016 (Table 5.6). This may reflect factors such as that Flint sending out approximately 1,800 shutoff notices of water services to residents for overdue accounts due to refusing to pay for contaminated water (Fonger, 2015).

Chapter 6. Conclusion

Evaluating public perceptions provides a better understanding of influential factors and is critical for successful decision making processes for managing infrastructure (Canter et al., 1993; Faust et al., 2016). Integrating different perspectives of the public is challenging, but important to minimize discontent toward infrastructure alternatives and infrastructure service providers, as well as increase the likelihood of implementing sustainable solutions (de França Doria, 2010; Faust et al., 2015). To the author's knowledge, current literature lacks an assessment of the temporal dynamics of public perception over time or the temporal impact of a specific event (e.g., the FWC explored in this study). In this study, the author evaluated whether the public perception of residents in shrinking cities toward water infrastructure providers has changed before and after the FWC. Then statistical modeling was conducted to assess geographic and demographic parameters that affect the likelihood of trust in water providers and wanting to partake in participatory processes of local utilities. This study found a measurable shift in public perception before and after the crisis and captured the temporal dynamics of perception. This study not only identified statistically significant parameters of two perceptions models (trust and participatory processes) in 2013 and 2016, but also sought to assess temporal changes in statistical significance of parameters.

Results from statistical modeling conducted in this study shows that a majority of the geographic (city and state) indicators were revealed as fixed parameters, demonstrating homogeneous impact on the likelihood of trusting water providers and wanting to partake in decision making processes of local utilities in both years. This implies that the likelihood for both *Trust* and *Active* are strongly impacted by localized factors. For example, cities or states that have more collaborative customer-utility relationships or local policies that facilitate communication between two parties may have influenced the likelihood of *Trust* and *Active*.

On the other hand, demographic parameters (i.e. home ownership, number of cars in a household, marital status, employment status, level of education, presence of youth in a household, and income) were more prevalent as random parameters, exhibiting heterogeneity across the population. In regard to temporal change in public perceptions, only two parameters (marital status and number of cars in a household) had the same (positive versus negative) impact on the likelihood of trusting water providers before and after the FWC, while no parameters for predicting likelihood to partake in participatory processes did. This demonstrates how public perceptions toward water infrastructure providers have changed between two time periods. The study presented captures the limitation of cross-sectional survey data that is often used in literature for public perceptions. Since perceptions are dynamic, changing constantly with new information and in light of new events, decisions making based on results from cross-sectional studies may provide incorrect information leading to unsustainable solutions for infrastructure systems.

Understanding which demographic parameters influence the likelihood to not trust local water providers is important to managing water infrastructure to mitigate potential opposition or public discontent. Furthermore, this can provide initial information for utility providers and cities with targeted groups they should reach out to improve the customer-utility relationship. This study also identifies individuals wanting to partake in participatory processes of local utilities, and thus, demographic groups (or locations) to focus on including in participatory processes. Utilities may also wish to reach out to those who do not want to partake to find out why, and attempt to identify other means to include these views in infrastructure decision making processes for sustainable decisions. From the statistical findings regarding geographic parameters show a list of cities in which the localized factors, such as utility-customer interactions has a homogeneous impact on residents' modeled perceptions.

6.1. CONTRIBUTION TO THE BODY OF KNOWLEDGE AND PRACTICE

The statistical modeling of this study found that most geographic parameters had homogeneous impacts, while demographic parameters had heterogeneous impacts on the likelihood of an individual's trust in his/her water provider and wanting to partake in participatory processes of local utilities. The homogeneous impact of geographic parameters demonstrates the localized significance of utility-customer relationships in shaping perceptions. This may imply that local level of strategies, policies, or events can be effective in gaining (or losing) public trust.

The temporal dynamics were effectively illustrated through statistically modeling, identifying the drastic change in demographic and geographic influential parameters between 2013 and 2016. The changes occurring between November 2013 and June 2016 had varying impacts on different demographics highlighting the heterogeneity of the population and the need to reevaluate the utility-customer relationships during rapidly changing climates. Using a LRT, this study demonstrated that cross-sectional surveys regarding infrastructure may provide inaccurate information to decision makers when new information, media attention, or events occur, effectively changing the operating environment of the infrastructure system. Additionally, this study demonstrated that there is a measurable, statistically significant shift in the public perceptions in shrinking cities, presumably due to the FWC.

6.2. LIMITATIONS

The two surveys analyzed were deployed to US shrinking cities that experienced steady population decline after the peak populations approximately 100,000 or more.

Therefore, the results cannot be applied to cities that are not categorized as shrinking cities. Another limitation of this study in the context of public perceptions is that all other factors that were not in scope of this study were not controlled between two time periods (2013 and 2016). Therefore, there is a possibility that other situations or events (e.g. not the FWC) that were not anticipated from this study influenced temporal dynamics of public perceptions toward water infrastructure providers between 2013 and 2016. Lastly, since perceptions constantly changes with new information and in light of new events, public perceptions toward water infrastructure providers in shrinking cities could have changed since the second survey deployed in June 2016.

6.3. FUTURE STUDIES

Further analysis with detailed case studies of identified cities or states that showed increased likelihood of *Trust* and *Active*, and interviews with SMEs from those cities and states in managing water infrastructure systems will enable shrinking cities to implement effective practices and strategies (e.g., right communication strategies between public and utilities) in the future. Inversely, future studies can focus on locations that experienced significant decrease in likelihood of *Trust* and *Active*. This may help to establish "lessons learned" for incorporating public perceptions to managing water infrastructures.

There is also a need for continued research on public perceptions. By conducting several different studies capturing temporal changes in public perceptions due to an event (FWC for this study), parameters that drives those dynamics in common can be identified. In this case, significant parameters that influence temporal dynamics can be understood more in general, resulting in more accurate representation of the reality.

Appendix A. Survey Deployed in 2013

What is your age?
- o 18-25 (1)
- o 26-35 (2)
- o 36-50 (3)
- o Above 50 (4)

City you reside in:________________

Over the past 4 decades, my city has:
- o A. Faced a loss in population. (1)
- o B. Gained population. (2)
- o C. Has had no significant changes in population. (3)
- o D. I do not know (4)

How has population change impacted the price of my water bill:
- o A. Decreasing my monthly water bill. (1)
- o B. Increasing my monthly water bill. (2)
- o C. It has not changed my monthly water bill at all. (3)
- o D. I do not know (4)

The present level of physical WATER infrastructure necessary to provide service to my city at its current population is:
- o A. More than enough water infrastructure. (1)
- o B. Not enough water infrastructure. (2)
- o C. The right amount of water infrastructure. (3)
- o D. I do not know (4)

My household uses an average of ____gallons of WATER per month (please enter "do not know" if applicable)

My WATER service bill is for:
- o Water service only. (1)
- o Water and wastewater service combined. (2)
- o I do not know (3)

Answer If My water service bill is for: Water and wastewater service combined Is Selected

My average combined monthly WASTEWATER and WATER bill is (please enter “do not know” if applicable)______

Answer If My water service bill is for: Water service only Is Selected Or My water service bill is for: I do not know Is Selected
My average monthly WATER bill is (please enter “do not know” if applicable)______

Answer If My water service bill is for: Water service only Is Selected And My water service bill is for: I do not know Is Selected
My average monthly WASTEWATER bill is (please enter “do not know” if applicable)______

Are you responsible for paying for your WATER bill or a portion of your WATER bill?
- o Yes (1)
- o No (2)

The amount of physical WATER infrastructure (e.g., pipes, reservoirs) in my city impacts the cost of my WATER bill.
- o Agree (1)
- o Disagree (2)
- o Do not know (3)

The quality (defined as uninterrupted, clean WATER, at an adequate pressure) of service from my WATER provider has changed in the past 10 years?
- o A. Not applicable, I have not lived in the city more than 10 years. (1)
- o B. The quality of service has decreased dramatically. (2)
- o C. The quality of service has decreased slightly. (3)
- o D. There is no noticeable change in service. (4)
- o E. The quality of service has improved slightly. (5)
- o F. The quality has improved dramatically. (6)

My city needs to (choose all that apply):
- o Invest in more water infrastructure. (1)
- o Remove or decommission (i.e., cease to use) components of the water infrastructure system. (2)
- o Repurpose some components of the water infrastructure system. (3)
- o Invest in maintaining the current water infrastructure system. (4)
- o Do nothing to the current water infrastructure system. (5)

Would you support decommissioning, razing, or repurposing WATER infrastructure (choose all that apply)?

- I would support decommissioning (i.e., ceasing to use, but leaving the components in place) components of my city's water infrastructure system. (1)
- I would support razing (i.e., removing) components of my city's water infrastructure system. (2)
- I would support repurposing (for instance, contracting out excess capacity, using wells as opposed to the citywide water grid) components of my city's water infrastructure system. (3)
- No, all components of my city's water infrastructure system should be in place for their current purposes. (4)

How much MORE would you be willing to pay for improved reliability of your WATER service? Leave the slider at "0" if you would not be willing to pay more for your water service for a more reliable system
______ Percent (%) increase in current water bill (1)

How much MORE would you be willing to pay for improved reliability of your WASTEWATER service? Leave the slider at "0" if you would not be willing to pay more for your water service for a more reliable system
______ Percent (%) increase in current wastewater bill (1)

Based on your understanding of the WATER infrastructure system, please indicate your opinion on the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	I do not know (6)
The water infrastructure system in my city is aging (i.e., very old) and needs to be upgraded (1)	❍	❍	❍	❍	❍	❍
The water infrastructure system in my city is sustained by revenues solely generated by water bills (2)	❍	❍	❍	❍	❍	❍
My water provider is fiscally strained (i.e., very tight on financial resources) (3)	❍	❍	❍	❍	❍	❍
I trust my water provider to make appropriate decisions	❍	❍	❍	❍	❍	❍

that are in my best interest (4)						
I would like to be actively involved in the decision-making process for the water infrastructure system in my city (5)	❍	❍	❍	❍	❍	❍

Based on your understanding of the WATER infrastructure system, please indicate your opinion on the following statements:

	Strongly Oppose (1)	Oppose (2)	Neutral (3)	Support (4)	Strongly Support (5)	I do not know (6)
New (e.g., new pipes, new reservoirs) water infrastructure projects in my city (1)	❍	❍	❍	❍	❍	❍
Increasing financial investments for the maintenance of the existing water infrastructure system in my city (2)	❍	❍	❍	❍	❍	❍
Decommissioning (i.e., ceasing to use, but leaving the components in place) components of my city's water infrastructure system (3)	❍	❍	❍	❍	❍	❍
Razing (i.e., removing) components of my city's water infrastructure system (4)	❍	❍	❍	❍	❍	❍
Repurposing components (for instance, contracting out excess capacity, using wells as opposed to the citywide water grid) of my city's water infrastructure system (5)	❍	❍	❍	❍	❍	❍
For validation purposes, please choose "oppose" (6)	❍	❍	❍	❍	❍	❍

Making improvements to my water infrastructure system that would increase the quality of the service AND increase the cost of service (7)	❍	❍	❍	❍	❍	❍
Changes to my water infrastructure system that would stabilize (i.e., stop rate increases) the cost of my service (e.g., upgrading or replacing infrastructure components) (8)	❍	❍	❍	❍	❍	❍
Increasing the cost of my water service to cover the cost of additional infrastructure or replacement (9)	❍	❍	❍	❍	❍	❍

Based on your understanding of your WASTEWATER infrastructure system, please indicate your opinion on the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	I do not know (6)
The wastewater infrastructure in my city is aging (i.e., very old) and needs to be upgraded (1)	❍	❍	❍	❍	❍	❍
Revenues solely generated by wastewater bills sustain the wastewater infrastructure system in my city (2)	❍	❍	❍	❍	❍	❍
My wastewater provider is fiscally strained (3)	❍	❍	❍	❍	❍	❍
I trust my wastewater provider to make appropriate decisions that are in my best interest (4)	❍	❍	❍	❍	❍	❍

Based on your understanding of your WASTEWATER infrastructure system, please indicate your opinion on the following statements:

	Strongly Oppose (1)	Oppose (2)	Neutral (3)	Support (4)	Strongly Support (5)	I do not know (6)
Increasing financial investments for the maintenance of the existing wastewater infrastructure system in my city (1)	❍	❍	❍	❍	❍	❍
For validation purposes, please choose "support" (2)	❍	❍	❍	❍	❍	❍
Decommissioning (i.e., ceasing to use, but leaving the components in place) components of my city's wastewater infrastructure system (3)	❍	❍	❍	❍	❍	❍
Razing (i.e., removing) components of my city's wastewater infrastructure system (4)	❍	❍	❍	❍	❍	❍
Repurposing components (for instance, contracting out excess capacity of sewer system for non-public purposes) of my city's wastewater infrastructure system (5)	❍	❍	❍	❍	❍	❍
Increasing the cost of my wastewater service to cover the cost of additional infrastructure or replacement (6)	❍	❍	❍	❍	❍	❍

The present level of physical WATER infrastructure necessary to provide service to my city at its current population is:

- o A. More than enough water infrastructure. (1)
- o B. Not enough water infrastructure. (2)
- o C. The right amount of water infrastructure. (3)

- D. I do not know (4)

Are you?
- Female (1)
- Male (2)

Marital Status:
- Single (1)
- Married (2)
- Civil Union (3)
- Divorced (4)
- Separated (5)

What is your identified ethnicity?
- Hispanic or Latino (1)
- Not Hispanic or Latino (2)

What is your identified race (choose all that apply)?
- American Indian or Alaska Native (1)
- Asian (2)
- Black or African American (3)
- Native Hawaiian or Other Pacific Islander (4)
- White (5)
- Other (6) ____________________

How would you classify the area you grew up in?
- Urban (1)
- Suburban (2)
- Rural (3)

Did you grow up in the city you are currently living in?
- Yes (1)
- No (2)

Were you born in the city you currently live in?
- Yes (1)
- No (2)

How long have you lived in your city?

What is the highest completed level of education?
- o Some high school (1)
- o High school diploma (2)
- o Technical college degree (3)
- o College Degree (4)
- o Post Graduate Degree (5)

How many people live in your household?

How many children under the age of 18 live your the household?

How many children under the age of 5 live in your household?

How many cars does your household have?

Is your household...?
- o Owned by you or someone in this household with a mortgage or loan (1)
- o Owned by you or someone in this household free and clear (without a mortgage or loan) (2)
- o Rented (3)
- o Other (4) ____________________

Is this the first household you have owned?
- o Yes (1)
- o No (2)
- o Not Applicable (3)

Answer If Is this the first household you have owned? Yes Is Selected
Length of time you have owned this home?

What is your approximate annual income?
- o No income (1)
- o Under $19,999 (2)
- o $20,000-$34,999 (3)
- o $35,000-$49,999 (4)
- o $50,000-$74,999 (5)
- o $75,000-99,999 (6)
- o $100,000 and above (7)

What is the approximate annual household income of the household you consider home?

- No income (1)
- Under $19,999 (2)
- $20,000-$34,999 (3)
- $35,000-$49,999 (4)
- $50,000-$74,999 (5)
- $75,000-99,999 (6)
- $100,000 and above (7)

Are you responsible for your water utility bill:
- Yes (1)
- No (2)

What is your employment status (choose all that apply)?
- Employed for wages or salary (1)
- Self-Employed (2)
- Out of work and looking for work (3)
- Out of work but not currently looking for work (4)
- A homemaker (5)
- A student (6)
- Retired (7)
- Unable to work (8)

What is your primary source of news (choose all that apply)?
- Newspaper (1)
- Internet (2)
- Television (3)
- Radio (4)
- Social Media (5)
- Other (6) ____________________

Frequency of following the news:
- At least once per day (1)
- At least once per week (2)
- At least once per month (3)
- Never (4)

Political Views:
- Republican (1)
- Democrat (2)

- Independent (3)
- Other (4) ____________________

Do you have any comments or concerns about the WATER infrastructure system in your city?

Do you have any comments or concerns about the WASTEWATER infrastructures system in your city?

Appendix B. Survey Redeployed in 2016

What is your age? 18-25 (1); 26-35 (2); 36-50 (3); Above 50 (4)

City you reside in:________________

Over the past 4 decades, my city has: Faced a loss in population. (1); Gained population. (2); Has had no significant changes in population. (3); I do not know (4)

How has population change impacted the price of my water bill:Decreasing my monthly water bill. (1); Increasing my monthly water bill. (2); It has not changed my monthly water bill at all. (3); I do not know (4)

The present level of physical WATER infrastructure necessary to provide service to my city at its current population is: More than enough water infrastructure. (1); Not enough water infrastructure. (2); The right amount of water infrastructure. (3); I do not know (4)

My household uses an average of ____gallons of WATER per month (please enter "do not know" if applicable)

My WATER service bill is for: Water service only. (1); Water and wastewater service combined. (2); I do not know (3)

Answer If My water service bill is for: Water and wastewater service combined Is Selected
My average combined monthly WASTEWATER and WATER bill is (please enter "do not know" if applicable)______

Answer If My water service bill is for: Water service only Is Selected Or My water service bill is for: I do not know Is Selected
My average monthly WATER bill is (please enter "do not know" if applicable)______

Answer If My water service bill is for: Water service only Is Selected And My water service bill is for: I do not know Is Selected
My average monthly WASTEWATER bill is (please enter "do not know" if applicable)______

Are you responsible for paying for your WATER bill or a portion of your WATER bill? Yes (1); No (2)

The amount of physical WATER infrastructure (e.g., pipes, reservoirs) in my city impacts the cost of my WATER bill. Agree (1); Disagree (2); Do not know (3)

The quality (defined as uninterrupted, clean WATER, at an adequate pressure) of service from my WATER provider has changed in the past 10 years?   Not applicable, I have not lived in the city more than 10 years. (1); The quality of service has decreased dramatically. (2);   The quality of service has decreased slightly. (3); There is no noticeable change in service. (4); The quality of service has improved slightly. (5); The quality has improved dramatically. (6)

My city needs to (choose all that apply):   Invest in more water infrastructure. (1); Remove or decommission (i.e., cease to use) components of the water infrastructure system. (2); Repurpose some components of the water infrastructure system. (3); Invest in maintaining the current water infrastructure system. (4); Do nothing to the current water infrastructure system. (5)

Would you support decommissioning, razing, or repurposing WATER infrastructure (choose all that apply)? I would support decommissioning (i.e., ceasing to use, but leaving the components in place) components of my city's water infrastructure system. (1); I would support razing (i.e., removing) components of my city's water infrastructure system. (2); I would support repurposing (for instance, contracting out excess capacity, using wells as opposed to the citywide water grid) components of my city's water infrastructure system. (3); No, all components of my city's water infrastructure system should be in place for their current purposes. (4)

How much MORE would you be willing to pay for improved reliability (quality, pressure and reduced interruption of service) of your WATER service?   Leave the slider at "0" if you would not be willing to pay more for your water service for a more reliable system______ Percent (%) increase in current water bill (1)

How much MORE would you be willing to pay for improved reliability of your WASTEWATER service?   Leave the slider at "0" if you would not be willing to pay more for your water service for a more reliable system
______ Percent (%) increase in current water bill (1)

Based on your understanding of the WATER infrastructure system, please indicate your opinion on the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	I do not know (6)
The water infrastructure system in my city is aging (i.e., very old) and needs to be upgraded (1)						

My water provider is fiscally strained (i.e., very tight on financial resources) (3)						
I trust my water provider to make appropriate decisions that are in my best interest (4)						
I have confidence in the water quality of your water delivered by the utility? (5)						
I would like to be actively involved in the decision-making process for the water infrastructure system in my city (6)						

Based on your understanding of the WATER infrastructure system, please indicate your opinion on the following statements:

	Strongly Oppose (1)	Oppose (2)	Neutral (3)	Support (4)	Strongly Support (5)	I do not know (6)
New (e.g., new pipes, new reservoirs) water infrastructure projects in my city (1)						
Increasing financial investments for the maintenance of the existing water infrastructure system in my city (2)						
Decommissioning (i.e., ceasing to use, but leaving the components in place) components of my city's water infrastructure system (3)						
Razing (i.e., removing) components of my city's water infrastructure system (4)						

Repurposing components (for instance, contracting out excess capacity, using wells as opposed to the citywide water grid) of my city's water infrastructure system (5)						
For validation purposes, please choose "oppose" (6)						
Making improvements to my water infrastructure system that would increase the quality of the service AND increase the cost of service (7)						
Changes to my water infrastructure system that would stabilize (i.e., stop rate increases) the cost of my service (e.g., upgrading or replacing infrastructure components) (8)						
Increasing the cost of my water service to cover the cost of additional infrastructure or replacement (9)						

I (my household) actively attempt(s) to conserve water? Yes (1); No (2)

I (my household) regularly has outdoor water use, such as watering the lawn? Yes (1); No (2)
If yes, how many TIMES PER WEEK do you use water outdoors? ________

I support using alternative sources (e.g., rainwater, reclaimed water, etc.. for outdoor water uses)? Strongly Disagree (1); Disagree (2) ; Neutral (3); Agree (4); Strongly Agree (5); I do not know (6)

On average, how many showers are taken daily in your household (including everyone in your household) ________
On average, how long (in minutes) are the showers ________

Based on your understanding of THE APPLIANCES IN YOUR HOME, please indicate your opinion on the following statements:

	Yes (1)	No (2)	I do not know (3)
I have low-flow appliances in your household (1)			
I have a low-flow washing machine (2)			
I have a low-flow dishwasher (3)			
I have AT LEAST one low-flow toilet (4)			
I collect rainwater for outdoor use (6)			
I have a home filter installed on my kitchen sink (7)			
I have a water filtration pitcher (e.g., Brita, ZeroWater) that is used regularly (8)			

I drink bottled water at home? Yes (1), No (2)

If yes, the frequency I drink bottled water at home is? Never (1); Occasionally (2); Most of the time (3); Primarily drink bottled water
If yes, why do you drink bottle water at home? __________

I drink filtered (e.g., installed filter on a sink, pitcher filter, etc) water at home? Yes (1), No (2)

If yes, the frequency I drink filtered water at home is? Never (1); Occasionally (2); Most of the time (3); Primarily drink filtered water
If yes, why do you drink filtered water at home? __________
If yes, how often do you change your filter?____________

I use filtered water for any other household tasks besides drinking water (e.g., showering, water plants)? Yes (1), No (2)
If yes, what tasks and why______________

I use bottled water for any other household tasks besides drinking water (e.g., showering, water plants)? Yes (1), No (2)
If so, what tasks and why______________

Did you know about your water utility's water quality report that comes out periodically? Yes (1); No (2)

Have you ever looked at/read your cities water quality report? Yes, I read every report (1); Yes, I read about one report per year (2); Yes, I have read at least one report (3); No, I have never read the report, but I know it exists (4); No, I did not know the report existed (5)

Based on your understanding of your WASTEWATER infrastructure system, please indicate your opinion on the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	I do not know (6)
The wastewater infrastructure in my city is aging (i.e., very old) and needs to be upgraded (1)						
Revenues solely generated by wastewater bills sustain the wastewater infrastructure system in my city (2)						
My wastewater provider is fiscally strained (3)						
I trust my wastewater provider to make appropriate decisions that are in my best interest (4)						

Who should be primarily responsible for paying for new capital intensive WATER infrastructure? Municipality (1); State (2); Federal government (3); Other _______(4)

Who should be primarily responsible for paying for maintaining WATER infrastructure? Municipality (1); State (2); Federal government (3); Other _______(4)

Who should be primarily responsible for paying for new capital intensive WASTEWATER infrastructure? Municipality (1); State (2); Federal government (3); Other _______(4)

Who should be primarily responsible for paying for maintaining WASTEWATER infrastructure? Municipality (1); State (2); Federal government (3); Other _______(4)
What type of disinfected does your city use? ______

The following infrastructure requires the most financial investment in my city due to its current physical (e.g., aging, failing, crumbling) state? Water Infrastructure (1); Transportation Infrastructure (2); Power Infrastructure (3); Other?___________ (4)

Based on your understanding of the transportation, water and power infrastructure systems, please indicate your opinion on the following statements:

	No connection/ interrelation (1)	Loosely connected/ interrelated (2)	Moderately connected/ interrelated (3)	Very connected/ interrelated (4)	I do not know (5)
How interconnected are TRANSPORTATION, WATER, and POWER infrastructure systems (1)					
How interconnected are TRANSPORTATION, and WATER (2)					
How interconnected are TRANSPORTATION, and POWER (3)					
How interconnected are POWER, and WATER (4)					
How interconnected are WATER and TRANSPORTAION infrastructure spending? (5)					
How interconnected are WATER and POWER infrastructure spending? (6)					
How interconnected are TRANSPORTATION and POWER					

infrastructure spending? (7)					

The present level of physical WATER infrastructure necessary to provide service to my city at its current population is: More than enough water infrastructure. (1); Not enough water infrastructure. (2); The right amount of water infrastructure. (3); I do not know (4)

Are you? Female (1); Male (2)

Marital Status: Single (1); Married (2); Civil Union (3); Divorced (4); Separated (5)

What is your identified ethnicity? Hispanic or Latino (1); Not Hispanic or Latino (2)

What is your identified race (choose all that apply)? American Indian or Alaska Native (1); Asian (2); Black or African American (3); Native Hawaiian or Other Pacific Islander (4); White (5); Other (6) ____________________

How would you classify the area you grew up in? Urban (1); Suburban (2); Rural (3)

Did you grow up in the city you are currently living in? Yes (1); No (2)

Were you born in the city you currently live in? Yes (1); No (2)

How long have you lived in your city?

What is the highest completed level of education? Some high school (1); High school diploma (2); Technical college degree (3); College Degree (4); Post Graduate Degree (5)

How many people live in your household?

How many children under the age of 18 live your the household?

How many children under the age of 5 live in your household?

How many cars does your household have?

Is your household...? Owned by you or someone in this household with a mortgage or loan (1); Owned by you or someone in this household free and clear (without a mortgage or loan) (2); Rented (3); Other (4) ______

Is this the first household you have owned? Yes (1); No (2); Not Applicable (3)
Answer If Is this the first household you have owned? Yes Is Selected

Length of time you have owned this home?

What is your approximate annual income? No income (1); Under $19,999 (2); $20,000-$34,999 (3); $35,000-$49,999 (4); $50,000-$74,999 (5); $75,000-99,999 (6); $100,000 and above (7)

What is the approximate annual household income of the household you consider home? No income (1); Under $19,999 (2); $20,000-$34,999 (3); $35,000-$49,999 (4); $50,000-$74,999 (5); $75,000-99,999 (6); $100,000 and above (7)

Are you responsible for your water utility bill: Yes (1); No (2)

What is your employment status (choose all that apply)? Employed for wages or salary (1); Self-Employed (2); Out of work and looking for work (3); Out of work but not currently looking for work (4); A homemaker (5); A student (6); Retired (7); Unable to work (8)

What is your primary source of news (choose all that apply)? Newspaper (1); Internet (2); Television (3); Radio (4); Social Media (5); Other (6) ____________________

Frequency of following the news: At least once per day (1); At least once per week (2); At least once per month (3); Never (4)

Political Views: Republican (1); Democrat (2); Independent (3); Other (4)
____

Do you have any comments or concerns about the WATER infrastructure system in your city?

Do you have any comments or concerns about the WASTEWATER infrastructures system in your city?

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